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(71) Applicant *(for all designated States except US)*: EXIQON A/S [DK/DK]; Bygstubben 9, DK–2950 Vedbæk (DK).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: WENGEL, Jesper [DK/DK]; Rugmarken 48, DK–5260 Odense S. (DK). NIELSEN, Poul [DK/DK]; Elmevangen 6, DK–7200 Grindsted (DK).

(74) Agent: PLOUGMANN, VINGTOFT & PARTNERS; Sankt Annæ Plads 11, P.O. Box 3007, DK–1021 Copenhagen (DK).

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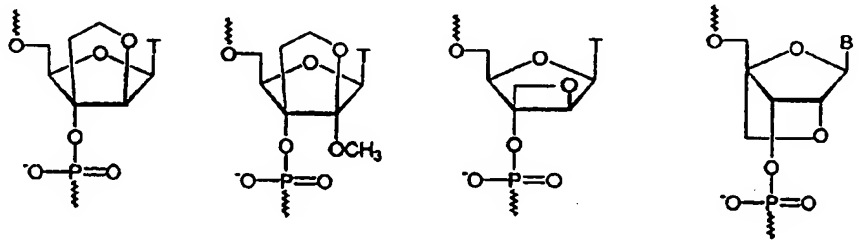


V X Y

ZT: B = thymin-1-yl
ZU: B = uracil-1-yl
ZG: B = guanin-9-yl
ZC: B = cytosin-1-yl
ZA: B = adenin-9-yl
ZMeC: B = 5-methylcytosin-1-yl

(57) Abstract

The present invention relates to novel bicyclic and tricyclic nucleoside and nucleotide analogues as well as to oligonucleotides comprising such elements. The nucleotide analogues, LNAs (Locked Nucleoside Analogues), are able to provide valuable improvements to oligonucleotides with respect to affinity and specificity towards complementary RNA and DNA oligomers. The novel type of LNA modified oligonucleotides, as well as the LNAs as such, are useful in a wide range of diagnostic applications as well as therapeutic applications. Among these can be mentionned antisense applications, PCR applications, strand displacement oligomers, as substrates for nucleic acid polymerases, as nucleotide based drugs, etc. The present invention also relates to such applications.

OLIGONUCLEOTIDE ANALOGUES

FIELD OF THE INVENTION

The present invention relates to the field of bi- and tricyclic nucleoside analogues and to the synthesis of such nucleoside analogues which are useful in the formation of synthetic oligonucleotides capable of forming nucleobase specific duplexes and triplexes with single stranded and double stranded nucleic acids. These complexes exhibit higher thermostability than the corresponding complexes formed with normal nucleic acids. The invention also relates to the field of bi- and tricyclic nucleoside analogues and the synthesis of such nucleosides which may be used as therapeutic drugs and which may be incorporated in oligonucleotides by template dependent nucleic acid polymerases.

BACKGROUND OF THE INVENTION

Synthetic oligonucleotides are widely used compounds in disparate fields such as molecular biology and DNA-based diagnostics and therapeutics.

Therapeutics

In therapeutics, *e.g.*, oligonucleotides have been used successfully to block translation in vivo of specific mRNAs thereby preventing the synthesis of proteins which are undesired or harmful to the cell/organism. This concept of oligonucleotide mediated blocking of translation is known as the "antisense" approach. Mechanistically, the hybridising oligonucleotide is thought to elicit its effect by either creating a physical block to the translation process or by recruiting cellular enzymes that specifically degrades the mRNA part of the duplex (RNAseH).

More recently, oligoribonucleotides and oligodeoxyribonucleotides and analogues thereof which combine RNAse catalytic activity with the ability to sequence specifically interact with a complementary RNA target (ribozymes) have attracted

Likewise, nucleosides and nucleoside analogues have proven effective in chemotherapy of numerous viral infections and cancers.

Also, various types of double-stranded RNAs have been shown to effectively inhibit the growth of several types of cancers.

Diagnostics

In molecular biology, oligonucleotides are routinely used for a variety of purposes such as for example (i) as hybridisation probes in the capture, identification and quantification of target nucleic acids (ii) as affinity probes in the purification of target nucleic acids (iii) as primers in sequencing reactions and target amplification processes such as the polymerase chain reaction (PCR) (iv) to clone and mutate nucleic acids and (vi) as building blocks in the assembly of macromolecular structures.

Diagnostics utilises many of the oligonucleotide based techniques mentioned above in particular those that lend themselves to easy automation and facilitate reproducible results with high sensitivity. The objective in this field is to use oligonucleotide based techniques as a means to, for example (i) tests humans, animals and food for the presence of pathogenic micro-organisms (ii) to test for genetic predisposition to a disease (iii) to identify inherited and acquired genetic disorders, (iv) to link biological deposits to suspects in crime trials and (v) to validate the presence of micro-organisms involved in the production of foods and beverages.

General considerations

To be useful in the extensive range of different applications outlined above, oligonucleotides have to satisfy a large number of different requirements. In antisense therapeutics, for instance, a useful oligonucleotide must be able to penetrate the cell membrane, have good resistance to extra- and intracellular nucleases and preferably have the ability to recruit endogenous enzymes like RNAseH. In DNA-based diagnostics and molecular biology other properties are important such as, *e.g.*, the ability of oligonucleotides to act as efficient substrates for a wide range of different enzymes evolved to act on natural nucleic acids, such as *e.g.* polymerases, kinases,

Conformationally restricted nucleosides

It is known that oligonucleotides undergo a conformational transition in the course of hybridising to a target sequence, from the relatively random coil structure of the single stranded state to the ordered structure of the duplex state.

A number of conformationally restricted oligonucleotides including bicyclic and tricyclic nucleoside analogues (Figure 1A and 1B in which B=nucleobase) have been synthesised, incorporated into oligonucleotide and oligonucleotide analogues and tested for their hybridisation and other properties.

Bicyclo[3.3.0] nucleosides (bcDNA) with an additional C-3´,C-5´-ethano-bridge (**A** and **B**) have been synthesised with all five nucleobases (G, A, T, C and U) whereas (**C**) has been synthesised only with T and A nucleobases (M. Tarköy, M. Bolli, B. Schweizer and C. Leumann, *Helv. Chim. Acta*, 1993, **76**, 481; Tarköy and C. Leumann, *Angew. Chem., Int. Ed. Engl.*, 1993, **32**, 1432; M. Egli, P. Lubini, M. Dobler and C. Leumann, *J. Am. Chem. Soc.*, 1993, **115**, 5855; M. Tarköy, M. Bolli and C. Leumann, *Helv. Chim. Acta*, 1994, **77**, 716; M. Bolli and C. Leumann, *Angew. Chem., Int. Ed. Engl.*, 1995, **34**, 694; M. Bolli, P. Lubini and C. Leumann, *Helv. Chim. Acta*, 1995, **78**, 2077; J. C. Litten, C. Epple and C. Leumann, *Bioorg. Med. Chem. Lett.*, 1995, **5**, 1231; J. C. Litten and C. Leumann, *Helv. Chim. Acta*, 1996, **79**, 1129; M. Bolli, J. C. Litten, R. Schültz and C. Leumann, *Chem. Biol.*, 1996, **3**, 197; M. Bolli, H. U. Trafelet and C. Leumann, *Nucleic Acids Res.*, 1996, **24**, 4660). DNA oligonucleotides containing a few, or being entirely composed, of these analogues are in most cases able to form Watson-Crick bonded duplexes with complementary DNA and RNA oligonucleotides. The thermostability of the resulting duplexes, however, is either distinctly lower (**C**), moderately lower (**A**) or comparable to (**B**) the stability of the natural DNA and RNA counterparts. All bcDNA oligomers exhibited a pronounced increase in sensitivity to the ionic strength of the hybridisation media compared to the natural counterparts. The α-bicyclo-DNA (**B**) is more stable towards the 3´-exonuclease snake venom phosphordiesterase than the β-bicyclo-DNA (**A**) which is only moderately more stable than unmodified oligonucleotides.

The two dimers (**G** and **H**) with additional C-2´,C-3´-dioxane rings forming bicyclic[4.3.0]-systems in acetal-type internucleoside linkages have been synthesised as T-T dimers and incorporated once in the middle of 12mer polypyrimidine oligonucleotides. Oligonucleotides containing either **G** or **H** both formed significantly less stable duplexes with complementary ssRNA and ssDNA compared with the unmodified control oligonucleotide (J. Wang and M. D. Matteucci, *Bioorg. Med. Chem. Lett.*, 1997, **7**, 229).

Dimers containing a bicyclo[3.1.0]nucleoside with a C-2´,C-3´-methano bridge as part of amide- and sulfonamide-type (**I** and **J**) internucleoside linkages have been synthesised and incorporated into oligonucleotides. Oligonucleotides containing one ore more of these analogues showed a significant reduction in T_m compared to unmodified natural oligonucleotide references (C. G. Yannopoulus, W. Q. Zhou, P. Nower, D. Peoch, Y. S. Sanghvi and G. Just, *Synlett*, 1997, 378).

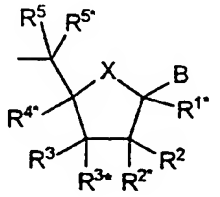
A trimer with formacetal internucleoside linkages and a bicyclo[3.3.0] glucose-derived nucleoside analogue in the middle (**K**) has been synthesised and connected to the 3´-end of an oligonucleotide. The T_m against complementary ssRNA was decreased by 4 °C, compared to a control sequence, and by 1.5 °C compared to a sequence containing two 2´,5´-formacetal linkages in the 3´-end (C. G. Yannopoulus, W. Q. Zhou, P. Nower, D. Peoch, Y. S. Sanghvi and G. Just, *Synlett*, 1997, 378).

Very recently oligomers composed of tricyclic nucleoside-analogues (**L**) have been reported to show increased duplex stability compared to natural DNA (R. Steffens and C. Leumann (Poster SB-B4), *Chimia*, 1997, **51**, 436).

Three bicyclic ([4.3.0] and [3.3.0]) nucleosides with an additional C-2´,C-3´-connected six- (**M** and **N**) or five-membered ring (**O**) have been synthesised as the T-analogues. The bicyclic nucleosides **M** and **N** have been incorporated once and twice into 14-mer oligo-T sequences. The T_m's against complementary ssRNA and ssDNA were decreased by 6-10 °C per modification compared to unmodified control sequences. Fully modified oligonucleotides of analogue **O** exhibited an increased T_m of approximately 1.0 °C per modification against the complementary RNA oligonucleotide

nucleoside analogues have been provided with all commonly used nucleobases thereby providing a full set of nucleoside analogues for incorporation in oligonucleotides. As will be apparent from the following, the LNA nucleoside analogues and the LNA modified oligonucleotide provides a wide range of improvements for oligonucleotides used in the fields of diagnostics and therapy. Furthermore, the LNA nucleoside analogues and the LNA modified oligonucleotide also provides completely new perspectives in nucleoside and oligonucleotide based diagnostics and therapy.

Thus, the present invention relates to oligomers comprising at least one nucleoside analogue (hereinafter termed "LNA") of the general formula I



I

wherein X is selected from -O-, -S-, -N(R^{N*})-, -C(R^6R^{6*})-, -O-C(R^7R^{7*})-, -C(R^6R^{6*})-O-, -S-C(R^7R^{7*})-, -C(R^6R^{6*})-S-, -N(R^{N*})-C(R^7R^{7*})-, -C(R^6R^{6*})-N(R^{N*})-, and -C(R^6R^{6*})-C(R^7R^{7*})-;

B is selected from hydrogen, hydroxy, optionally substituted C_{1-4}-alkoxy, optionally substituted C_{1-4}-alkyl, optionally substituted C_{1-4}-acyloxy, nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands;

P designates the radical position for an internucleoside linkage to a succeeding monomer, or a 5'-terminal group, such internucleoside linkage or 5'-terminal group optionally including the substituent R^5;

one of the substituents R^2, R^{2*}, R^3, and R^{3*} is a group P* which designates an internucleoside linkage to a preceding monomer, or a 3'-terminal group;

one or two pairs of non-geminal substituents selected from the present substituents of R^{1*}, R^{4*}, R^5, R^{5*}, R^6, R^{6*}, R^7, R^{7*}, R^{N*}, and the ones of R^2, R^{2*}, R^3, and R^{3*} not

photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, where aryl and heteroaryl may be optionally substituted, and where two geminal substituents together may designate oxo, thioxo, imino, or optionally substituted methylene, or together may form a spiro biradical consisting of a 1-5 carbon atom(s) alkylene chain which is optionally interrupted and/or terminated by one or more heteroatoms/groups selected from -O-, -S-, and -(NR^N)- where R^N is selected from hydrogen and C_{1-4}-alkyl, and where two adjacent (non-geminal) substituents may designate an additional bond resulting in a double bond; and R^{N*}, when present and not involved in a biradical, is selected from hydrogen and C_{1-4}-alkyl;

and basic salts and acid addition salts thereof;

with the proviso that,

(i) R^2 and R^3 do not together designate a biradical selected from -O-CH_2-CH_2- and -O-CH_2-CH_2-CH_2- when LNA is a bicyclic nucleoside analogue;

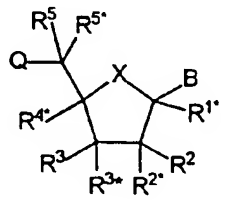
(ii) R^3 and R^5 do not together designate a biradical selected from -CH_2-CH_2-, -O-CH_2-, when LNA is a bicyclic nucleoside analogue;

(iii) R^3, R^5, and R^{5*} do not together designate a triradical -CH_2-CH(-)-CH_2- when LNA is a tricyclic nucleoside analogue;

(iv) R^{1*} and R^{6*} do not together designate a biradical -CH_2- when LNA is a bicyclic nucleoside analogue; and

(v) R^{4*} and R^{6*} do not together designate a biradical -CH_2- when LNA is a bicyclic nucleoside analogue.

The present invention furthermore relates to nucleoside analogues (hereinafter LNAs) of the general formula II



II

(vi) R^{1*} and R^{4*} together designate a biradical selected from -$(CR^*R^*)_r$-O-$(CR^*R^*)_s$-, -$(CR^*R^*)_r$-S-$(CR^*R^*)_s$-, and -$(CR^*R^*)_r$-N(R^*)-$(CR^*R^*)_s$-;

(vii) R^{1*} and R^{2*} together designate a biradical selected from -$(CR^*R^*)_r$-O-$(CR^*R^*)_s$-, -$(CR^*R^*)_r$-S-$(CR^*R^*)_s$-, and -$(CR^*R^*)_r$-N(R^*)-$(CR^*R^*)_s$-;

wherein each R^* is independently selected from hydrogen, halogen, azido, cyano, nitro, hydroxy, mercapto, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R^* may together designate a double bond, and each of r and s is 0-3 with the proviso that the sum r+s is 1-4;

each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{4*}, R^5, and R^{5*}, which are not involved in Q, Q* or the biradical, is independently selected from hydrogen, optionally substituted C_{1-12}-alkyl, optionally substituted C_{2-12}-alkenyl, optionally substituted C_{2-12}-alkynyl, hydroxy, C_{1-12}-alkoxy, C_{2-12}-alkenyloxy, carboxy, C_{1-12}-alkoxycarbonyl, C_{1-12}-alkylcarbonyl, formyl, aryl, aryloxy-carbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxy-carbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, azido, sulphanyl, C_{1-6}-alkylthio, halogen, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, where aryl and heteroaryl may be optionally substituted, and where two geminal substituents together may designate oxo, thioxo, imino, or optionally substituted methylene, or together may form a spiro biradical consisting of a 1-5 carbon atom(s) alkylene chain which is optionally interrupted and/or terminated by one or more heteroatoms/groups selected from -O-, -S-, and -(NR^N)- where R^N is selected from hydrogen and C_{1-4}-alkyl, and where two adjacent (non-geminal) substituents may designate an additional bond resulting in a double bond; and R^{N*}, when present and not involved in a biradical, is selected from hydrogen and C_{1-4}-alkyl;

and basic salts and acid addition salts thereof;

Figure 7 illustrates that LNA modified oligonucleotides can function as primers for nucleic acid polymerases.

Figure 8 illustrates that LNA modified oligonucleotides can functions as primers in target amplification processes.

Figure 9 illustrates that LNA modified oligonucleotides carrying a 5´anthraquinone can be covalently immobilised on a solid support by irradiation and that the immobilised oligomer is efficient in the capture of a complementary DNA oligo.

Figure 10 illustrates that LNA-thymidine-5'-triphosphate (LNA-TTP) can act as a substrate for terminal deoxynucleotidyl transferase (TdT).

Figure 11 illustrates hybridisation and detection on an array with different LNA modified Cy3-labelled 8mers.

Figures 12 and 13 illustrate hybridisation and detection of end mismatches on an array with LNA modified Cy3-labelled 8mers.

Figure 14 illustrates blockade by LNA of [D-Ala2]deltorphin-induced antinociception in the warm water tail flick test in conscious rats.

Figures 15A, 15B, and 15C illustrate Hybridization and detection of end mismatches on an array with AT and all LNA modified Cy3-labelled 8mers.

Figures 16 and 17 illustrate that LNA can be delivered to living human MCF-7 breast cancer cells.

Figures 18 and 19 illustrate the use of [α^{33}P] ddNTP's and ThermoSequenase™ DNA Polymerase to sequence DNA templates containing LNA T monomers.

Figures 20 and 21 illustrate that exonuclease free Klenow fragment DNA polymerase I can incorporate LNA Adenosine, Cytosine, Guanosine and Uridine-5'-triphosphates into a DNA strand.

wherein X is selected from -O- (the furanose motif), -S-, -N(R^{N*})-, -C(R^6R^{6*})-, -O-C(R^7R^{7*})-, -C(R^6R^{6*})-O-, -S-C(R^7R^{7*})-, -C(R^6R^{6*})-S-, -N(R^{N*})-C(R^7R^{7*})-, -C(R^6R^{6*})-N(R^{N*})-, and -C(R^6R^{6*})-C(R^7R^{7*})-, where R^6, R^{6*}, R^7, R^{7*}, and R^{N*} are as defined further below. Thus, the LNAs incorporated in the oligomer may comprise an either 5- or 6-membered ring as an essential part of the bi-, tri-, or polycyclic structure. It is believed that 5-membered rings (X = -O-, -S-, -N(R^{N*})-, -C(R^6R^{6*})-) are especially interesting in that they are able to occupy essentially the same conformations (however locked by the introduction of one or more biradicals (see below)) as the native furanose ring of a naturally occurring nucleoside. Among the possible 5-membered rings, the situations where X designates -O-, -S-, and -N(R^{N*})- seem especially interesting, and the situation where X is -O- appears to be particularly interesting.

The substituent B may designate a group which, when the oligomer is complexing with DNA or RNA, is able to interact (*e.g.* by hydrogen bonding or covalent bonding or electronic interaction) with DNA or RNA, especially nucleobases of DNA or RNA. Alternatively, the substituent B may designate a group which acts as a label or a reporter, or the substituent B may designate a group (*e.g.* hydrogen) which is expected to have little or no interactions with DNA or RNA. Thus, the substituent B is preferably selected from hydrogen, hydroxy, optionally substituted C_{1-4}-alkoxy, optionally substituted C_{1-4}-alkyl, optionally substituted C_{1-4}-acyloxy, nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands.

In the present context, the terms "nucleobase" covers naturally occurring nucleobases as well as non-naturally occurring nucleobases. It should be clear to the person skilled in the art that various nucleobases which previously have been considered "non-naturally occurring" have subsequently been found in nature. Thus, "nucleobase" includes not only the known purine and pyrimidine heterocycles, but also heterocyclic analogues and tautomers thereof. Illustrative examples of nucleobases are adenine, guanine, thymine, cytosine, uracil, purine, xanthine, diaminopurine, 8-oxo-N^6-methyladenine, 7-deazaxanthine, 7-deazaguanine, N^4,N^4-ethanocytosin, N^6,N^6-ethano-2,6-diaminopurine, 5-methylcytosine, 5-(C^3-C^6)-alkynylcytosine, 5-fluorouracil, 5-bromouracil, pseudoisocytosine, 2-hydroxy-5-methyl-4-triazolopyridin, isocytosine,

In the present context, the term "chelating group" means a molecule that contains more than one binding site and frequently binds to another molecule, atom or ion through more than one binding site at the same time. Examples of functional parts of chelating groups are iminodiacetic acid, nitrilotriacetic acid, ethylenediamine tetraacetic acid (EDTA), aminophosphonic acid, etc.

In the present context, the term "reporter group" means a group which is detectable either by itself or as a part of an detection series. Examples of functional parts of reporter groups are biotin, digoxigenin, fluorescent groups (groups which are able to absorb electromagnetic radiation, *e.g.* light or X-rays, of a certain wavelength, and which subsequently reemits the energy absorbed as radiation of longer wavelength; illustrative examples are dansyl (5-dimethylamino)-1-naphthalenesulfonyl), DOXYL (N-oxyl-4,4-dimethyloxazolidine), PROXYL (N-oxyl-2,2,5,5-tetramethylpyrrolidine), TEMPO (N-oxyl-2,2,6,6-tetramethylpiperidine), dinitrophenyl, acridines, coumarins, Cy3 and Cy5 (trademarks for Biological Detection Systems, Inc.), erytrosine, coumaric acid, umbelliferone, texas red, rhodamine, tetramethyl rhodamine, Rox, 7-nitrobenzo-2-oxa-1-diazole (NBD), pyrene, fluorescein, Europium, Ruthenium, Samarium, and other rare earth metals), radioisotopic labels, chemiluminescence labels (labels that are detectable via the emission of light during a chemical reaction), spin labels (a free radical (*e.g.* substituted organic nitroxides) or other paramagnetic probes (*e.g.* Cu^{2+}, Mg^{2+}) bound to a biological molecule being detectable by the use of electron spin resonance spectroscopy), enzymes (such as peroxidases, alkaline phosphatases, β-galactosidases, and glycose oxidases), antigens, antibodies, haptens (groups which are able to combine with an antibody, but which cannot initiate an immune response by itself, such as peptides and steroid hormones), carrier systems for cell membrane penetration such as: fatty acid residues, steroid moieties (cholesteryl), vitamin A, vitamin D, vitamin E, folic acid peptides for specific receptors, groups for mediating endocytose, epidermal growth factor (EGF), bradykinin, and platelet derived growth factor (PDGF). Especially interesting examples are biotin, fluorescein, Texas Red, rhodamine, dinitrophenyl, digoxigenin, Ruthenium, Europium, Cy5, Cy3, etc.

In the present context "ligand" means something which binds. Ligands can comprise functional groups such as: aromatic groups (such as benzene, pyridine, naphtalene,

In the present context, the term "spacer" means a thermochemically and photochemically non-active distance-making group and is used to join two or more different moieties of the types defined above. Spacers are selected on the basis of a variety of characteristics including their hydrophobicity , hydrophilicity, molecular flexibility and length (*e.g.* see Hermanson et. al., "Immobilized Affinity Ligand Techniques", Academic Press, San Diego, California (1992), p. 137-ff). Generally, the length of the spacers are less than or about 400 Å, in some applications preferably less than 100 Å. The spacer, thus, comprises a chain of carbon atoms optionally interrupted or terminated with one or more heteroatoms, such as oxygen atoms, nitrogen atoms, and/or sulphur atoms. Thus, the spacer K may comprise one or more amide, ester, amino, ether, and/or thioether functionalities, and optionally aromatic or mono/polyunsaturated hydrocarbons, polyoxyethylene such as polyethylene glycol, oligo/polyamides such as poly-β-alanine, polyglycine, polylysine, and peptides in general, oligosaccharides, oligo/polyphosphates. Moreover the spacer may consist of combined units thereof. The length of the spacer may vary, taking into consideration the desired or necessary positioning and spatial orientation of the "active/functional" part of the group in question in relation to the 5- or 6-membered ring. In particularly interesting embodiments, the spacer includes a chemically cleavable group. Examples of such chemically cleavable groups include disulphide groups cleavable under reductive conditions, peptide fragments cleavable by peptidases, etc.

In one embodiment of the present invention, K designates a single bond so that the "active/functional" part of the group in question is attached directly to the 5- or 6-membered ring.

In a preferred embodiment, the substituent B in the general formulae I and II is preferably selected from nucleobases, in particular from adenine, guanine, thymine, cytosine and urasil.

In the oligomers of the present invention (formula I), P designates the radical position for an internucleoside linkage to a succeeding monomer, or a 5'-terminal group. The first possibility applies when the LNA in question is not the 5'-terminal "monomer", whereas the latter possibility applies when the LNA in question is the 5'-terminal "monomer". It should be understood (which also will be clear from the definition of

existence of some of the substituents, *i.e.* R^6, R^{6*}, R^7, R^{7*}, R^{N*}, is dependent on whether X includes such substituents.)

In the groups constituting the biradical(s), Z is selected from -O-, -S-, and -N(R^a)-, and R^a and R^b each is independently selected from hydrogen, optionally substituted C_{1-12}-alkyl, optionally substituted C_{2-12}-alkenyl, optionally substituted C_{2-12}-alkynyl, hydroxy, C_{1-12}-alkoxy, C_{2-12}-alkenyloxy, carboxy, C_{1-12}-alkoxycarbonyl, C_{1-12}-alkylcarbonyl, formyl, aryl, aryloxy-carbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxy-carbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, azido, sulphanyl, C_{1-6}-alkylthio, halogen, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands (where the latter groups may include a spacer as defined for the substituent B), where aryl and heteroaryl may be optionally substituted. Moreover, two geminal substituents R^a and R^b together may designate optionally substituted methylene (=CH_2 optionally substituted one or two times with substituents as defined as optional substituents for aryl), and two non-geminal or geminal substituents selected from R^a, R^b, and any of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, R^{5*}, R^6 and R^{6*}, R^7, and R^{7*} which are present and not involved in P, P^* or the biradical(s) may together form an associated biradical selected from biradicals of the same kind as defined before. It will be clear that each of the pair(s) of non-geminal substituents thereby forms a mono- or bicyclic entity together with (i) the atoms to which the non-geminal substituents are bound and (ii) any intervening atoms.

It is believed that biradicals which are bound to the ring atoms of the 5- or 6-membered rings are preferred in that inclusion of the substituents R^5 and R^{5*} may cause an undesired sterical interaction with internucleoside linkage. Thus, it is preferred that the one or two pairs of non-geminal substituents, which are constituting one or two biradical(s), respectively, are selected from the present substituents of R^{1*}, R^{4*}, R^6, R^{6*}, R^7, R^{7*}, R^{N*}, and the ones of R^2, R^{2*}, R^3, and R^{3*} not designating P^*.

from -(CR*R*)$_r$-Y-(CR*R*)$_s$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-Y-, -Y-(CR*R*)$_{r+s}$-Y-, -Y-(CR*R*)$_r$-Y-(CR*R*)$_s$-, -(CR*R*)$_{r+s}$-, -Y-, -Y-Y-, wherein each Y is independently selected from -O-, -S-, -Si(R*)$_2$-, -N(R*)-, >C=O, -C(=O)-N(R*)-, and -N(R*)-C(=O)-, each R* is independently selected from hydrogen, halogen, azido, cyano, nitro, hydroxy, mercapto, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R* may together designate a double bond; and each of r and s is 0-4 with the proviso that the sum r+s is 1-5. Particularly interesting situations are those wherein each biradical is independently selected from -Y-, -(CR*R*)$_{r+s}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-, wherein and each of r and s is 0-3 with the proviso that the sum r+s is 1-4.

Considering the positioning of the biradical in the LNA(s), it is believed (based on the preliminary findings (see the examples)) that the following situations are especially interesting, namely where: R^{2*} and R^{4*} together designate a biradical selected from -Y-, -(CR*R*)$_{r+s+1}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; R^2 and R^3 together designate a biradical selected from -Y-, -(CR*R*)$_{r+s}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; R^{2*} and R^3 together designate a biradical selected from -Y-, -(CR*R*)$_{r+s}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; R^3 and R^{4*} together designate a biradical selected from -Y-, -(CR*R*)$_{r+s}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; R^3 and R^5 together designate a biradical selected from -Y'-, -(CR*R*)$_{r+s+1}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; R^{1*} and R^{4*} together designate a biradical selected from -Y'-, -(CR*R*)$_{r+s+1}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-NR*-; or where R^{1*} and R^{2*} together designate a biradical selected from -Y-, -(CR*R*)$_{r+s}$-, -(CR*R*)$_r$-Y-(CR*R*)$_s$-, and -Y-(CR*R*)$_{r+s}$-Y-; wherein each of r and s is 0-3 with the proviso that the sum r+s is 1-4, Y is as defined above, and where Y' is selected from -NR*-C(=O)- and -C(=O)-NR*-.

Particularly interesting oligomers are those wherein one of the following criteria applies for at least one LNA in an oligomer: R^{2*} and R^{4*} together designate a biradical selected from -O-, -S-, -N(R*)-, -(CR*R*)$_{r+s+1}$-, -(CR*R*)$_r$-O-(CR*R*)$_s$-, -(CR*R*)$_r$-S-(CR*R*)$_s$-, -(CR*R*)$_r$-N(R*)-(CR*R*)$_s$-, -O-(CR*R*)$_{r+s}$-O-, -S-(CR*R*)$_{r+s}$-O-, -O-(CR*R*)$_{r+s}$-S-, -N(R*)-(CR*R*)$_{r+s}$-O-, -O-(CR*R*)$_{r+s}$-N(R*)-, -S-(CR*R*)$_{r+s}$-S-, -N(R*)-(CR*R*)$_{r+s}$-N(R*)-, -N(R*)-

chelating groups, reporter groups, and ligands (where the latter groups may include a spacer as defined for the substituent B), where aryl and heteroaryl may be optionally substituted, and where two geminal substituents together may designate oxo, thioxo, imino, or optionally substituted methylene, or together may form a spiro biradical consisting of a 1-5 carbon atom(s) alkylene chain which is optionally interrupted and/or terminated by one or more heteroatoms/groups selected from -O-, -S-, and -(NR^N)- where R^N is selected from hydrogen and C_{1-4}-alkyl, and where two adjacent (non-geminal) substituents may designate an additional bond resulting in a double bond; and R^{N*}, when present and not involved in a biradical, is selected from hydrogen and C_{1-4}-alkyl.

Preferably, each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, R^{5*}, R^6, R^{6*}, R^7, and R^{7*} of the LNA(s), which are present and not involved in P, P* or the biradical(s), is independently selected from hydrogen, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, hydroxy, C_{1-6}-alkoxy, C_{2-6}-alkenyloxy, carboxy, C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, azido, C_{1-6}-alkanoyloxy, sulphono, sulphanyl, C_{1-6}-alkylthio, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and halogen, where two geminal substituents together may designate oxo, and where R^{N*}, when present and not involved in a biradical, is selected from hydrogen and C_{1-4}-alkyl.

In a preferred embodiment of the present invention, X is selected from -O-, -S-, and -NR^{N*}-, in particular -O-, and each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, R^{5*}, R^6, R^{6*}, R^7, and R^{7*} of the LNA(s), which are present and not involved in P, P* or the biradical(s), designate hydrogen.

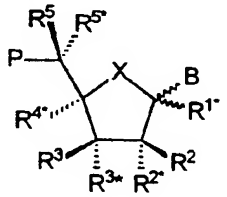
In an even more preferred embodiment of the present invention, R^{2*} and R^{4*} of an LNA incorporated into an oligomer together designate a biradical. Preferably, X is O, R^2 selected from hydrogen, hydroxy, and optionally substituted C_{1-6}-alkoxy, and R^{1*}, R^3, R^5, and R^{6*} designate hydrogen, and, more specifically, the biradical is selected from -O-, -$(CH_2)_{0-1}$-O-$(CH_2)_{1-3}$-, -$(CH_2)_{0-1}$-S-$(CH_2)_{1-3}$-, -$(CH_2)_{0-1}$-N(R^N)-$(CH_2)_{1-3}$-, and -$(CH_2)_{2-4}$-, in particular from -O-CH_2-, -S-CH_2-, and -NR^H-CH_2-. Generally, with due regard to the

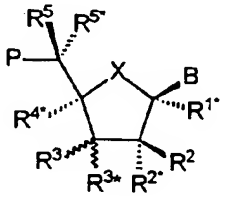
In these embodiments, it is furthermore preferred that at least one LNA incorporated in an oligomer includes a nucleobase (substituent B) selected from adenine and guanine. In particular, it is preferred that an oligomer have LNA incorporated therein both include at least one nucleobase selected from thymine, urasil and cytosine and at least one nucleobase selected from adenine and guanine. For LNA monomers, it is especially preferred that the nucleobase is selected from adenine and guanine.

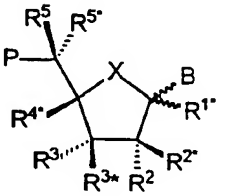
For these interesting embodiments, it is also preferred that the LNA(s) has/have the general formula Ia (see below).

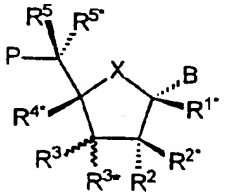
Within a variant of these interesting embodiments, all monomers of a oligonucleotide are LNA monomers.

As it will be evident from the general formula I (LNA(s) in an oligomer) (and the general formula II (monomeric LNA) - see below) and the definitions associated therewith, there may be one or several asymmetric carbon atoms present in the oligomers (and monomeric LNAs) depending on the nature of the substituents and possible biradicals, cf. below. The oligomers prepared according to the method of the invention, as well as the oligomers per se, are intended to include all stereoisomers arising from the presence of any and all isomers of the individual monomer fragments as well as mixtures thereof, including racemic mixtures. When considering the 5- or 6-membered ring, it is, however, believed that certain stereochemical configurations will be especially interesting, *e.g.* the following









naturally occurring bases, *e.g.* adenine, guanine, cytosine, thymine, and uracil, as well as any modified variants thereof or any possible unnatural bases.

When considering the definitions and the known nucleosides (naturally occurring and non-naturally occurring) and nucleoside analogues (including known bi- and tricyclic analogues), it is clear that an oligomer may comprise one or more LNA(s) (which may be identical or different both with respect to the selection of substituent and with respect to selection of biradical) and one or more nucleosides and/or nucleoside analogues. In the present context "oligonucleotide" means a successive chain of nucleosides connected via internucleoside linkages, however, it should be understood that a nucleobase in one or more nucleotide units (monomers) in an oligomer (oligonucleotide) may have been modified with a substituent B as defined above.

The oligomers may be linear, branched or cyclic. In the case of a branched oligomer, the branching points may be located in a nucleoside, in an internucleoside linkage or, in an intriguing embodiment, in an LNA. It is believed that in the latter case, the substituents R^2, R^{2*}, R^3, and R^{3*} may designate two groups P* each designating an internucleoside linkage to a preceding monomer, in particular, one of R^2 and R^{2*} designate P^* and one or R^3 and R^{3*} designate a further P^*.

As mentioned above, the LNA(s) of an oligomer are connected with other monomers via an internucleoside linkage. In the present context, the term "internucleoside linkage" means a linkage consisting of 2 to 4, preferably 3, groups/atoms selected from $-CH_2-$, $-O-$, $-S-$, $-NR^H-$, $>C=O$, $>C=NR^H$, $>C=S$, $-Si(R'')_2-$, $-SO-$, $-S(O)_2-$, $-P(O)_2-$, $-PO(BH_3)-$, $-P(O,S)-$, $-P(S)_2-$, $-PO(R'')-$, $-PO(OCH_3)-$, and $-PO(NHR^H)-$, where R^H is selected form hydrogen and C_{1-4}-alkyl, and R'' is selected from C_{1-6}-alkyl and phenyl. Illustrative examples of such internucleoside linkages are $-CH_2-CH_2-CH_2-$, $-CH_2-CO-CH_2-$, $-CH_2-CHOH-CH_2-$, $-O-CH_2-O-$, $-O-CH_2-CH_2-$, $-O-CH_2-CH=$ (including R^5 when used as a linkage to a succeeding monomer), $-CH_2-CH_2-O-$, $-NR^H-CH_2-CH_2-$, $-CH_2-CH_2-NR^H-$, $-CH_2-NR^H-CH_2-$, $-O-CH_2-CH_2-NR^H-$, $-NR^H-CO-O-$, $-NR^H-CO-NR^H-$, $-NR^H-CS-NR^H-$, $-NR^H-C(=NR^H)-NR^H-$, $-NR^H-CO-CH_2-NR^H-$, $-O-CO-O-$, $-O-CO-CH_2-O-$, $-O-CH_2-CO-O-$, $-CH_2-CO-NR^H-$, $-O-CO-NR^H-$, $-NR^H-CO-CH_2-$, $-O-CH_2-CO-NR^H-$, $-O-CH_2-CH_2-NR^H-$, $-CH=N-O-$, $-CH_2-NR^H-O-$, $-CH_2-O-N=$ (including R^6 when used as a linkage to a succeeding monomer), $-CH_2-O-NR^H-$, $-CO-NR^H-CH_2-$, $-CH_2-NR^H-O-$, $-CH_2-NR^H-CO-$, $-O-NR^H-CH_2-$,

Analogously, the group P* may designate a 3'-terminal group in the case where the LNA in question is the 3'-terminal monomer. Examples of such 3'-terminal groups are hydrogen, hydroxy, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkylcarbonyloxy, optionally substituted aryloxy, and -W-A', wherein W is selected from -O-, -S-, and -N(R^H)- where R^H is selected from hydrogen and C_{1-6}-alkyl, and where A' is selected from DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands (where the latter groups may include a spacer as defined for the substituent B).

In a preferred embodiment of the present invention, the oligomer has the following formula V:

$$G\text{-}[Nu\text{-}L]_{n(0)}\text{-}\{[LNA\text{-}L]_{m(q)}\text{-}[Nu\text{-}L]_{n(q)}\}_q\text{-}G^* \qquad V$$

wherein

q is 1-50;

each of n(0), .., n(q) is independently 0-10000;

each of m(1), .., m(q) is independently 1-10000;

with the proviso that the sum of n(0), .., n(q) and m(1), .., m(q) is 2-15000;

G designates a 5'-terminal group;

each Nu independently designates a nucleoside selected from naturally occurring nucleosides and nucleoside analogues;

each LNA independently designates a nucleoside analogue;

each L independently designates an internucleoside linkage between two groups selected from Nu and LNA, or L together with G* designates a 3'-terminal group; and

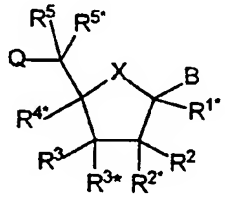
each LNA-L independently designates a nucleoside analogue of the general formula I as defined above, or preferably of the general formula Ia as defined above.

Within this embodiment, as well as generally, the present invention provides the intriguing possibility of including LNAs with different nucleobases, in particular both nucleobases selected from thymine, cytosine and urasil and nucleobases selected from adenine and guanine.

The oligomers of the present invention are also intended to cover chimeric oligomers. "Chimeric oligomers" means two or more oligomers with monomers of different origin joined either directly or via a spacer. Illustrative examples of such oligomers which can be combined are peptides, PNA-oligomers, oligomers containing LNA's, and oligonucleotide oligomers.

Apart from the oligomers defined above, the present invention also provides monomeric LNAs useful, *e.g.*, in the preparation of oligomers, as substrates for, *e.g.*, nucleic acid polymerases, polynucleotide kinases, terminal transferases, and as therapeutical agents, see further below. The monomeric LNAs correspond in the overall structure (especially with respect to the possible biradicals) to the LNAs defined as constituents in oligomers, however with respect to the groups P and P*, the monomeric LNAs differ slightly as will be explained below. Furthermore, the monomeric LNAs may comprise functional group protecting groups, especially in the cases where the monomeric LNAs are to be incorporated into oligomers by chemical synthesis.

An interesting subgroup of the possible monomeric LNAs comprises bicyclic nucleoside analogues (LNAs) of the general formula II



II

wherein the substituent B is selected from nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands; X is selected from -O-, -S-, -N(R^{N*})-, and -C(R^6R^{6*})-, preferably from -O-, -S-, and -N(R^{N*})-; one of the substituents R^2, R^{2*}, R^3, and R^{3*} is a group Q*;

each of Q and Q* is independently selected from hydrogen, azido, halogen, cyano, nitro, hydroxy, Prot-O-, Act-O-, mercapto, Prot-S-, Act-S-, C_{1-6}-alkylthio, amino, Prot-N(R^H)-, Act-N(R^H)-, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy,

nucleobase), which is reactive under the conditions prevailing in chemical oligonucleotide synthesis, is optionally functional group protected as known in the art. This means that groups such as hydroxy, amino, carboxy, sulphono, and mercapto groups, as well as nucleobases, of a monomeric LNA are optionally functional group protected. Protection (and deprotection) is performed by methods known to the person skilled in the art (see, *e.g.*, Greene, T. W. and Wuts, P. G. M., "Protective Groups in Organic Synthesis", 2nd ed., John Wiley, N.Y. (1991), and M.J. Gait, Oligonucleotide Synthesis, IRL Press, 1984).

Illustrative examples of hydroxy protection groups are optionally substituted trityl, such as 4,4'-dimethoxytrityl (DMT), 4-monomethoxytrityl (MMT), and trityl, optionally substituted 9-(9-phenyl)xanthenyl (pixyl), optionally substituted ethoxycarbonyloxy, *p*-phenylazophenyloxycarbonyloxy, tetraahydropyranyl (thp), 9-fluorenylmethoxycarbonyl (Fmoc), methoxytetrahydropyranyl (mthp), silyloxy such as trimethylsilyl (TMS), triisopropylsilyl (TIPS), *tert*-butyldimethylsilyl (TBDMS), triethylsilyl, and phenyldimethylsilyl, benzyloxycarbonyl or substituted benzyloxycarbonyl ethers such as 2-bromo benzyloxycarbonyl, *tert*-butylethers, alkyl ethers such as methyl ether, acetals (including two hydroxy groups), acyloxy such as acetyl or halogen substituted acetyls, *e.g.* chloroacetyl or fluoroacetyl, isobutyryl, pivaloyl, benzoyl and substituted benzoyls, methoxymethyl (MOM), benzyl ethers or substituted benzyl ethers such as 2,6-dichlorobenzyl (2,6-Cl_2Bzl). Alternatively, the hydroxy group may be protected by attachment to a solid support optionally through a linker.

Illustrative examples of amino protection groups are Fmoc (fluorenylmethoxycarbonyl), BOC (*tert*-butyloxycarbonyl), trifluoroacetyl, allyloxycarbonyl (alloc, AOC), benzyloxycarbonyl (Z, Cbz), substituted benzyloxycarbonyls such as 2-chloro benzyloxycarbonyl ((2-ClZ), monomethoxytrityl (MMT), dimethoxytrityl (DMT), phthaloyl, and 9-(9-phenyl)xanthenyl (pixyl).

Illustrative examples of carboxy protection groups are allyl esters, methyl esters, ethyl esters, 2-cyanoethylesters, trimethylsilylethylesters, benzyl esters (Obzl), 2-adamantyl esters (O-2-Ada), cyclohexyl esters (OcHex), 1,3-oxazolines, oxazoler, 1,3-oxazolidines, amides or hydrazides.

substituted C_{2-6}-alkynyl, optionally substituted C_{2-6}-alkynyloxy, monophosphate, diphosphate, triphosphate, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, ligands, carboxy, sulphono, hydroxymethyl, Prot-O-CH_2-, aminomethyl, Prot-N(R^H)-CH_2-, carboxymethyl, sulphonomethyl, and R^H is selected from hydrogen and C_{1-6}-alkyl.

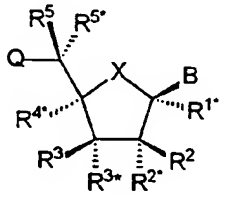
In the case described above, the group Prot designates a protecting group for -OH, -SH, and -NH(R^H), respectively. Such protection groups are selected from the same as defined above for hydroxy protection groups, mercapto protection group, and amino protection groups, respectively, however taking into consideration the need for a stable and reversible protection group. However, it is preferred that any protection group for -OH is selected from optionally substituted trityl, such as dimethoxytrityl (DMT), monomethoxytrityl (MMT), and trityl, and 9-(9-phenyl)xanthenyl (pixyl), optionally substituted, tetrahydropyranyl (thp) (further suitable hydroxy protection groups for phosphoramidite oligonucleotide synthesis are described in Agrawal, ed. "Protocols for Oligonucleotide Conjugates"; Methods in Molecular Biology, vol. 26, Humana Press, Totowa, NJ (1994) and Protocols for Oligonucleotides and Analogs, vol 20, (Sudhir Agrawal, ed.), Humana Press, 1993, Totowa, NJ), or protected as acetal; that any protection group for -SH is selected from trityl, such as dimethoxytrityl (DMT), monomethoxytrityl (MMT), and trityl, and 9-(9-phenyl)xanthenyl (pixyl), optionally substituted, tetrahydropyranyl (thp) (further suitable mercapto protection groups for phosphoramidite oligonucleotide synthesis are also described in Agrawal (see above); and that any protecting group for -NH(R^H) is selected from trityl, such as dimethoxytrityl (DMT), monomethoxytrityl (MMT), and trityl, and 9-(9-phenyl)xanthenyl (pixyl), optionally substituted, tetrahydropyranyl (thp) (further suitable amino protection groups for phosphoramidite oligonucleotide synthesis are also described in Agrawal (see above).

In the embodiment above, as well as for any monomeric LNAs defined herein, Act designates an activation group for -OH, -SH, and -NH(R^H), respectively. Such activation groups are, *e.g.*, selected from optionally substituted O-phosphoramidite, optionally substituted O-phosphortriester, optionally substituted O-phosphordiester, optionally substituted H-phosphonate, and optionally substituted O-phosphonate.

Act is an activation group for -OH, -SH, and -NH(R^H), respectively, and R^H is selected from hydrogen and C_{1-6}-alkyl.

The monomeric LNAs of the general formula II may, as the LNAs incorporated into oligomers, represent various stereoisomers. Thus, the stereochemical variants described above for the LNAs incorporated into oligomers are believed to be equally applicable in the case of monomeric LNAs (however, it should be noted that P should then be replaced with Q).

In a preferred embodiment of the present invention, the monomeric LNA has the general formula IIa



IIa

wherein the substituents are defined as above.

Furthermore, with respect to the definitions of substituents, biradicals, R^*, etc. the same preferred embodiments as defined above for the oligomer according to the invention also apply in the case of monomeric LNAs.

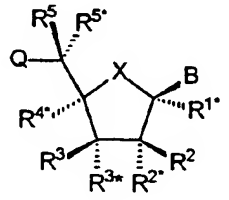
In a particularly interesting embodiment of the monomeric LNAs of the present invention, B designates a nucleobase, preferably a nucleobase selected from thymine, cytosine, urasil, adenine and guanine (in particular adenine and guanine), X is -O-, R^{2*} and R^{4*} together designate a biradical selected from -$(CH_2)_{0-1}$-O-$(CH_2)_{1-3}$-, -$(CH_2)_{0-1}$-S-$(CH_2)_{1-3}$-, and -$(CH_2)_{0-1}$-N(R^N)-$(CH_2)_{1-3}$-, in particular -O-CH_2-, -S-CH_2- and -R^N-CH_2-, where R^N is selected from hydrogen and C_{1-4}-alkyl, Q designates Prot-O-, R^{3*} is Q^* which designates Act-OH, and R^{1*}, R^2, R^3, R^5, and R^{5*} each designate hydrogen. In this embodiment, R^N may also be selected from DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups and ligands.

monomers suitable for incorporation of (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(cytosin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(urasil-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(guanin-1-yl)-2,5-dioxabicyclo-[2.2.1]heptane, and (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(adenin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane using the phosphoramidite approach, the phosphortriester approach, and the *H*-phosphonate approach, respectively, are (*1R,3R,4R,7S*)-7-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-1-(4,4'-dimethoxytrityloxymethyl)-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1R,3R,4R,7S*)-7-hydroxy-1-(4,4'-dimethoxytrityloxymethyl)-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane-7-*O*-(2-chlorophenylphosphate), and (*1R,3R,4R,7S*)-7-hydroxy-1-(4,4'-dimethoxytrityloxymethyl)-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane-7-*O*-(*H*-phosphonate) and the 3-(cytosin-1-yl), 3-(urasil-1-yl), 3-(adenin-1-yl) and 3-(guanin-1-yl) analogues thereof, respectively. Furthermore, the analogues where the methyleneoxy biradical of the monomers is substituted with a methylenethio, a methyleneamino, or a 1,2-ethylene biradical are also expected to constitute particularly interesting variants within the present invention. The methylenethio and methyleneamino analogues are believed to equally applicable as the methyleneoxy analogue and therefore the specific reagents corresponding to those mentioned for incorporation of (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(cytosin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(urasil-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(guanin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane, and (*1S,3R,4R,7S*)-7-hydroxy-1-hydroxymethyl-3-(adenin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane should also be considered as particularly interesting reactive monomers within the present invention. For the methyleneamine analogue, it should be noted that the secondary amine may carry a substituent selected from optionally substituted C_{1-6}-alkyl such as methyl and benzyl, optionally substituted C_{1-6}-alkylcarbonyl such as trifluoroacetyl, optionally substituted arylcarbonyl and optionally substituted heteroarylcarbonyl.

In a particularly interesting embodiment, the present invention relates to an oligomer comprising at least one LNA of the general formula Ia

Especially, the biradical is selected from -O-, $-(CH_2)_{0-1}-O-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-S-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-N(R^N)-(CH_2)_{1-3}-$, and $-(CH_2)_{2-4}-$.

In a further particularly interesting embodiment, the present invention relates to an LNA of the general formula IIa



IIa

wherein X is -O-; B is selected from nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands; R^{3*} is a group Q*; each of Q and Q* is independently selected from hydrogen, azido, halogen, cyano, nitro, hydroxy, Prot-O-, Act-O-, mercapto, Prot-S-, Act-S-, C_{1-6}-alkylthio, amino, Prot-N(R^H)-, Act-N(R^H)-, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyl, optionally substituted C_{2-6}-alkynyloxy, monophosphate, diphosphate, triphosphate, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, ligands, carboxy, sulphono, hydroxymethyl, Prot-O-CH_2-, Act-O-CH_2-, aminomethyl, Prot-N(R^H)-CH_2-, Act-N(R^H)-CH_2-, carboxymethyl, sulphonomethyl, where Prot is a protection group for -OH, -SH, and -NH(R^H), respectively, Act is an activation group for -OH, -SH, and -NH(R^H), respectively, and R^H is selected from hydrogen and C_{1-6}-alkyl; R^{2*} and R^{4*} together designate a biradical selected from -O-, -S, -N(R^*)-, $-(CR^*R^*)_{r+s+1}-$, $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$, $-O-(CR^*R^*)_{r+s}-O-$, $-S-(CR^*R^*)_{r+s}-O-$, $-O-(CR^*R^*)_{r+s}-S-$, $-N(R^*)-(CR^*R^*)_{r+s}-O-$, $-O-(CR^*R^*)_{r+s}-N(R^*)-$, $-S-(CR^*R^*)_{r+s}-S-$, $-N(R^*)-(CR^*R^*)_{r+s}-N(R^*)-$, $-N(R^*)-(CR^*R^*)_{r+s}-S-$, and $-S-(CR^*R^*)_{r+s}-N(R^*)-$; wherein each R^* is independently selected from hydrogen, halogen, azido, cyano, nitro, hydroxy, mercapto, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R^* may together designate a double bond, and each of r and s is 0-3 with the proviso that the sum r+s is 1-4; each of the substituents R^{1*}, R^2, R^3, R^5, and R^{5*} is

preferably at least 5.0 x N °C higher, in particular at least 6.0 x N °C higher, especially at least 7.0 x N°C higher, where N is the number of nucleoside analogues.

The term "corresponding unmodified reference oligonucleotide" is intended to mean an oligonucleotide solely consisting of naturally occurring nucleotides which represents the same nucleobases in the same absolute order (and the same orientation).

The T_m is measured under one of the following conditions (i.e. essentially as illustrated in Example 129):

a) 10mM Na_2HPO_4, pH 7.0, 100mM NaCl, 0.1mM EDTA;
b) 10mM Na_2HPO_4 pH 7.0, 0.1mM EDTA; or
c) 3M tetrametylammoniumchlorid (TMAC), 10mM Na_2HPO_4, pH 7.0, 0.1mM EDTA;

preferably under conditions a), at equimolar amounts (typically 1.0 µM) of the oligomer and the complementary DNA oligonucleotide.

The oligomer is preferably as defined above, where the at least one nucleoside analogue has the formula I where B is a nucleobase. In particular interesting is the cases where at least one nucleoside analogue includes a nucleobase selected from adenine and guanine.

Furthermore, with respect to specificity and affinity, the oligomer, when hybridised with a partially complementary DNA oligonucleotide, or a partially complementary RNA oligonucleotide, having one or more mismatches with said oligomer, should exhibit a reduction in T_m, as a result of said mismatches, which is equal to or greater than the reduction which would be observed with the corresponding unmodified reference oligonucleotide which does not comprise any nucleoside analogues. Also, the oligomer should have substantially the same sensitivity of T_m to the ionic strength of the hybridisation buffer as that of the corresponding unmodified reference oligonucleotide.

Oligomers defined herein are typically at least 30% modified, preferably at least 50% modified, in particular 70% modified, and in some interesting applications 100% modified.

In the present context, *i.e.* in connection with the terms "alkyl", "alkenyl", and "alkynyl", the term "optionally substituted" means that the group in question may be substituted one or several times, preferably 1-3 times, with group(s) selected from hydroxy (which when bound to an unsaturated carbon atom may be present in the tautomeric keto form), C_{1-6}-alkoxy (*i.e.* C_{1-6}-alkyl-oxy), C_{2-6}-alkenyloxy, carboxy, oxo (forming a keto or aldehyde functionality), C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, aryl, aryloxycarbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxycarbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino; carbamoyl, mono- and di(C_{1-6}-alkyl)aminocarbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkylcarbonylamino, cyano, guanidino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, sulphanyl, C_{1-6}-alkylthio, halogen, where any aryl and heteroaryl may be substituted as specifically describe below for "optionally substituted aryl and heteroaryl".

Preferably, the substituents are selected from hydroxy, C_{1-6}-alkoxy, carboxy, C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, aryl, aryloxycarbonyl, arylcarbonyl, heteroaryl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-aminocarbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkylcarbonylamino, cyano, carbamido, halogen, where aryl and heteroaryl may be substituted 1-5 times, preferably 1-3 times, with C_{1-4}-alkyl, C_{1-4}-alkoxy, nitro, cyano, amino or halogen. Especially preferred examples are hydroxy, C_{1-6}-alkoxy, carboxy, aryl, heteroaryl, amino, mono- and di(C_{1-6}-alkyl)amino, and halogen, where aryl and heteroaryl may be substituted 1-3 times with C_{1-4}-alkyl, C_{1-4}-alkoxy, nitro, cyano, amino or halogen.

In the present context the term "aryl" means a fully or partially aromatic carbocyclic ring or ring system, such as phenyl, naphthyl, 1,2,3,4-tetrahydronaphthyl, anthracyl, phenanthracyl, pyrenyl, benzopyrenyl, fluorenyl and xanthenyl, among which phenyl is a preferred example.

The term "heteroaryl" means a fully or partially aromatic carbocyclic ring or ring system where one or more of the carbon atoms have been replaced with heteroatoms, *e.g.* nitrogen (=N- or -NH), sulphur, and/or oxygen atoms. Examples of such heteroaryl groups are oxazolyl, isoxazolyl, thiazolyl, isothiazolyl, pyrrolyl, imidazolyl,

17. Ed. Alfonso R. Gennaro (Ed.), Mack Publishing Company, Easton, PA, U.S.A., 1985 and more recent editions and in Encyclopedia of Pharmaceutical Technology. Thus, the term "an acid addition salt or a basic salt thereof" used herein is intended to comprise such salts. Furthermore, the oligomers and LNAs as well as any intermediates or starting materials therefor may also be present in hydrate form.

Preparation of monomers

In a preferred embodiment, nucleosides containing an additional 2'-*O*,4'-*C*-linked ring were synthesised by the following procedure:

Synthesis of a number of 4'-*C*-hydroxymethyl nucleosides have been reported earlier (R. D. Youssefyeh, J. P. H. Verheyden and J. G. Moffatt, *J. Org. Chem.*, 1979, 44, 1301; G. H. Jones, M. Taniguchi, D. Tegg and J. G. Moffatt, *J. Org. Chem.*, 1979, 44, 1309; C. O-Yang, H. Y. Wu, E. B. Fraser-Smith and K. A. M. Walker, *Tetrahedron Lett.*, 1992, 33, 37; H. Thrane, J. Fensholdt, M. Regner and J. Wengel, *Tetrahedron*, 1995, 51, 10389; K. D. Nielsen, F. Kirpekar, P. Roepstorff and J. Wengel, *Bioorg. Med. Chem.*, 1995, 3, 1493). For exemplification of synthesis of 2'-*O*,4'-*C*-linked bicyclic nucleosides we chose a strategy starting from 4'-*C*-hydroxymethyl furanose derivative **31**. Benzylation, acetylation, and acetolysis followed by another acetylation afforded furanose **33**, a key intermediate for nucleoside coupling. Stereoselective reaction with silylated thymine afforded compound **34** which was deacetylated to give nucleoside diol **35**. Tosylation followed by base-induced ring closure afforded the 2'-*O*,4'-*C*-linked bicyclic nucleoside derivative **36**. Debenzylation yielded the unprotected bicyclic nucleoside analogue **37** which was transformed into the 5'-*O*-4,4'-dimethoxytrityl protected analogue **38** and subsequently into the phosphoramidite derivative **39** for oligonucleotide synthesis. A similar procedure has been used for synthesis of the corresponding uracil, adenine, cytosine and guanine nucleosides as exemplified in the example section. This coupling method is only one of several possible as will be apparent for a person skilled in the art. A strategy starting from a preformed nucleoside is also possible. Thus, for example, conversion of uridine derivative **62** to derivative **44** was successfully accomplished by tosylation, deisopropylidination and base-induced ring-closure. As another example, conversion of nucleoside **67** into nucleoside **61B** has been accomplished as depicted in Figure 34.

established in the field of organic chemistry, synthesis of for example thio analogues of the exemplified oxo analogues is possible as is the synthesis of the corresponding amino analogues (using for example nucleophilic substitution reactions or reductive alkylations).

In the example section, synthesis of the amino LNA analogues **73-74F** are described. Conversion of **74** and **74D** into standard building blocks for oligomerisation was possible by 5'-*O*-DMT protection and 3'-*O*-phosphitylation following the standard procedures. For the amino LNA analogue, protection of the 2'-amino functionality is needed for controlled linear oligomerisation. Such protection can be accomplished using standard amino group protection techniques like, *e.g.*, Fmoc, trifluoroacetyl or BOC. Alternatively, an N-alkyl group (*e.g.* benzyl, methyl, ethyl, propyl or functionalised alkyl) can be kept on during nucleoside transformations and oligomerisation. In Figures 35 and 36, strategies using N-trifluoroacetyl and N-methyl derivatives are shown. As outlined in Figure 37, conversion of nucleoside **75** into the 2'-thio-LNA nucleoside analogue **76D** has been successfully performed as has the subsequent syntheses of the phosphoramidite derivative **76F**. Compound **76F** has the required structure for automated synthesis of 2'-thio-LNA oligonucleotides. The N-trifluoroacetyl 2'-amino-LNA synthon **74A** has the required structure for automated synthesis of 2'-amino-LNA oligonucleotides.

Synthesis of the corresponding cytosine, guanine, and adenine derivatives of the 2'-thio and 2'-amino LNA nucleosides can be accomplished using strategies analogous to those shown in Figures 35, 36 and 37. Alternative, the stereochemistry around C-2' can be inverted before cyclisations either by using a conveniently configurated, *e.g.* an arabino-configurated, furanose synthon, or by inverting the configuration around the C-2' carbon atom starting from a ribo-configurated nucleoside/furanose. Subsequent activation of the 2'-β-OH, *e.g.* by tosylation, double nucleophilic substitution as in the urasil/thymine example described above, could furnish the desired bicyclic 2'-thio-LNA or 2'-amino-LNA nucleosides. The thus obtained properly protected cytosine, guanine, and adenine analogues can be prepared for oligomerisation using the standard reactions (DMT-protection and phosphitylation) as described above for other examples.

and to verify that the desired number of bicyclic nucleoside analogues of the invention were incorporated as contemplated.

An additional aspect of the present invention is to furnish procedures for oligonucleotide analogues containing LNA linked by non-natural internucleoside linkages. For example, synthesis of the corresponding phosphorothioate or phosphoramidate analogues is possible using strategies well-established in the field of oligonucleotide chemistry (Protocols for Oligonucleotides and Analogs, vol 20, (Sudhir Agrawal, ed.), Humana Press, 1993, Totowa, NJ; S. L. Beaucage and R. P. Iyer, *Tetrahedron*, 1993, 49, 6123; S. L. Beaucage and R. P. Iyer, *Tetrahedron*, 1992, 48, 2223; E. Uhlmann and A. Peyman, *Chem. Rev.*, 90, 543).

Thus, generally the present invention also provides the use of an LNA as defined herein for the preparation of an LNA modified oligonucleotides. Is should be understood that LNA modified oligonucleotide may comprise normal nucleosides (i.e. naturally occurring nucleosides such as ribonucleosides and/or dioxyribonucleosides), as well as modified nucleosides different from those defined with the general formula II. In a particularly interesting embodiment, incorporation of LNA modulates the ability of the oligonucleotide to act as a substrate for nucleic acid active enzymes.

Furthermore, solid support materials having immobilised thereto an optionally nucleobase protected and optionally 5'-OH protected LNA are especially interesting as material for the synthesis of LNA modified oligonucleotides where an LNA monomer is included in at the 3' end. In this instance, the solid support material is preferable CPG, *e.g.* a readily (commercially) available CPG material onto which a 3'-functionalised, optionally nucleobase protected and optionally 5'-OH protected LNA is linked using the conditions stated by the supplier for that particular material. BioGenex Universial CPG Support (BioGenex, U.S.A.) can e.g. be used. The 5'-OH protecting group may, *e.g.*, be a DMT group. 3'-functional group should be selected with due regard to the conditions applicable for the CPG material in question.

Another object of the present invention is to provide fully or partly LNA modified oligonucleotides (oligomers) that are able to hybridise in a sequence specific manner to complementary oligonucleotides forming either duplexes or triplexes of substantially higher affinity than the corresponding complexes formed by unmodified oligonucleotides.

Another object of the present invention is to use LNAs to enhance the specificity of normal oligonucleotides without compromising affinity. This can be achieved by reducing the size (and therefore affinity) of the normal oligonucleotide to an extent that equals the gain in affinity resulting from the incorporation of LNAs.

Another object of the present invention is to provide fully or partly modified oligonucleotides containing both LNAs, normal nucleosides and other nucleoside analogues.

A further object of the present invention is to exploit the high affinity of LNAs to create modified oligonucleotides of extreme affinity that are capable of binding to their target sequences in a dsDNA molecule by way of "strand displacement".

A further object of the invention is to provide different classes of LNAs which, when incorporated into oligonucleotides, differ in their affinity towards their complementary nucleosides. In accordance with the invention this can be achieved by either substituting the normal nucleobases G, A, T, C and U with derivatives having, for example, altered hydrogen bonding possibilities or by using LNAs that differ in their backbone structure. The availability of such different LNAs facilitates exquisite tuning of the affinity of modified oligonucleotides.

Another object of the present invention is to provide LNA modified oligonucleotides which are more resistant to nucleases than their unmodified counterparts.

Another object of the present invention is to provide LNA modified oligonucleotides which can recruit RNAseH.

The present invention also provides the use of LNA modified oligonucleotides in nucleic acid based therapeutic, diagnostics and molecular biology. The LNA modified oligonucleotides can be used in the detection, identification, capture, characterisation, quantification and fragmentation of natural or synthetic nucleic acids, and as blocking agents for translation and transcription *in vivo* and *in vitro*. In many cases it will be of interest to attach various molecules to LNA modified oligonucleotides. Such molecules may be attached to either end of the oligonucleotide or they may be attached at one or more internal positions. Alternatively, they may be attached to the oligonucleotide via spacers attached to the 5' or 3' end. Representative groups of such molecules are DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands. Generally all methods for labelling unmodified DNA and RNA oligonucleotides with these molecules can also be used to label LNA modified oligonucleotides. Likewise, all methods used for detecting labelled oligonucleotides generally apply to the corresponding labelled, LNA modified oligonucleotides.

Therapy

The term "strand displacement" relates to a process whereby an oligonucleotide binds to its complementary target sequence in a double stranded DNA or RNA so as to displace the other strand from said target strand.

In an aspect of the present invention, LNA modified oligonucleotides capable of performing "strand displacement" are exploited in the development of novel pharmaceutical drugs based on the "antigene" approach. In contrast to oligonucleotides capable of making triple helices, such "strand displacement" oligonucleotides allow any sequence in a dsDNA to be targeted and at physiological ionic strength and pH.

The "strand displacing" oligonucleotides can also be used advantageously in the antisense approach in cases where the RNA target sequence is inaccessible due to intramolecular hydrogen bonds. Such intramolecular structures may occur in mRNAs and can cause significant problems when attempting to "shut down" the translation of the mRNA by the antisense approach.

LNA monomer as defined above in combination with a pharmaceutically acceptable carrier.

Such compositions may be in a form adapted to oral, parenteral (intravenous, intraperitoneal), intramuscular, rectal, intranasal, dermal, vaginal, buccal, ocularly, or pulmonary administration, preferably in a form adapted to oral administration, and such compositions may be prepared in a manner well-known to the person skilled in the art, e.g. as generally described in "Remington's Pharmaceutical Sciences", 17. Ed. Alfonso R. Gennaro (Ed.), Mark Publishing Company, Easton, PA, U.S.A., 1985 and more recent editions and in the monographs in the "Drugs and the Pharmaceutical Sciences" series, Marcel Dekker.

Diagnostics

Several diagnostic and molecular biology procedures have been developed that utilise panels of different oligonucleotides to simultaneously analyse a target nucleic acid for the presence of a plethora of possible mutations. Typically, the oligonucleotide panels are immobilised in a predetermined pattern on a solid support such that the presence of a particular mutation in the target nucleic acid can be revealed by the position on the solid support where it hybridises. One important prerequisite for the successful use of panels of different oligonucleotides in the analysis of nucleic acids is that they are all specific for their particular target sequence under the single applied hybridisation condition. Since the affinity and specificity of standard oligonucleotides for their complementary target sequences depend heavily on their sequence and size this criteria has been difficult to fulfil so far.

In a preferred embodiment, therefore, LNAs are used as a means to increase affinity and/or specificity of the probes and as a means to equalise the affinity of different oligonucleotides for their complementary sequences. As disclosed herein such affinity modulation can be accomplished by, *e.g.*, replacing selected nucleosides in the oligonucleotide with an LNA carrying a similar nucleobase. As further shown herein, different classes of LNAs exhibit different affinities for their complementary nucleosides. For instance, the 2-3 bridged LNA with the T-nucleobase exhibits less affinity for the A-nucleoside than the corresponding 2-4 bridged LNA. Hence, the use

In still another aspect, LNA modified oligonucleotides capable of performing "strand displacement" are used in the capture of natural and synthetic nucleic acids without prior denaturation. Such modified oligonucleotides are particularly useful in cases where the target sequence is difficult or impossible to access by normal oligonucleotides due to the rapid formation of stable intramolecular structures. Examples of nucleic acids containing such structures are rRNA, tRNA, snRNA and scRNA.

In another preferred embodiment, LNA modified oligonucleotides designed with the purpose of high specificity are used as primers in the sequencing of nucleic acids and as primers in any of the several well known amplification reactions, such as the PCR reaction. As shown herein, the design of the LNA modified oligonucleotides determines whether it will sustain a exponential or linear target amplification. The products of the amplification reaction can be analysed by a variety of methods applicable to the analysis of amplification products generated with normal DNA primers. In the particular case where the LNA modified oligonucleotide primers are designed to sustain a linear amplification the resulting amplicons will carry single stranded ends that can be targeted by complementary probes without denaturation. Such ends could for instance be used to capture amplicons by other complementary LNA modified oligonucleotides attached to a solid surface.

In another aspect, LNA modified oligos capable of "strand displacement" are used as primers in either linear or exponential amplification reactions. The use of such oligos is expected to enhance overall amplicon yields by effectively competing with amplicon re-hybridisation in the later stages of the amplification reaction. Demers, et al. (Nucl. Acid Res. 1995, Vol 23, 3050-3055) discloses the use of high-affinity, non-extendible oligos as a means of increasing the overall yield of a PCR reaction. It is believed that the oligomers elicit these effect by interfering with amplicon re-hybridisation in the later stages of the PCR reaction. It is expected that LNA modified oligos blocked at their 3' end will provide the same advantage. Blocking of the 3' end can be achieved in numerous ways like for instance by exchanging the 3' hydroxyl group with hydrogen or phosphate. Such 3' blocked LNA modified oligos can also be used to selectively amplify closely related nucleic acid sequences in a way similar to that described by Yu et al. (Biotechniques, 1997, 23, 714-716).

instance polypropylene, polystyrene, polycarbonate or polyethylene. The affinity pairs may be used in selective isolation, purification, capture and detection of a diversity of the target molecules mentioned above.

The principle of capturing an LNA-tagged molecule by ways of interaction with another complementary LNA oligonucleotide (either fully or partially modified) can be used to create an infinite number of novel affinity pairs.

In another preferred embodiment the high affinity and specificity of LNA modified oligonucleotides are exploited in the construction of probes useful in *in-situ* hybridisation. For instance, LNA could be used to reduce the size of traditional DNA probes whilst maintaining the required affinity thereby increasing the kinetics of the probe and its ability to penetrate the sample specimen. The ability of LNA modified oligonucleotides to "strand invade" double stranded nucleic acid structures are also of considerable advantage in in-situ hybridisation, because it facilitates hybridisation without prior denaturation of the target DNA/RNA.

In another preferred embodiment, LNA modified oligonucleotides to be used in antisense therapeutics are designed with the dual purpose of high affinity and ability to recruit RNAseH. This can be achieved by, for instance, having LNA segments flanking an unmodified central DNA segment.

The present invention also provides a kit for the isolation, purification, amplification, detection, identification, quantification, or capture of natural or synthetic nucleic acids, where the kit comprises a reaction body and one or more LNA modified oligonucleotides (oligomer) as defined herein. The LNA modified oligonucleotides are preferably immobilised onto said reactions body.

The present invention also provides a kit for the isolation, purification, amplification, detection, identification, quantification, or capture of natural or synthetic nucleic acids, where the kit comprises a reaction body and one or more LNAs as defined herein. The LNAs are preferably immobilised onto said reactions body (e.g. by using the immobilising techniques described above).

EXPERIMENTAL

General

All reagents were obtained from commercial suppliers and were used without further purification. After drying any organic phase using Na_2SO_4, filtration was performed. The silica gel (0.040-0.063 mm) used for column chromatography was purchased from Merck. NMR spectra were recorded at 300 MHz or 250 MHz for ^1H NMR and 62.9 MHz for ^{13}C NMR and at 202.33 MHz for ^{31}P NMR. δ-Values are in ppm relative to tetramethylsilane as internal standard (^1H NMR and ^{13}C NMR) and relative to 85% H_3PO_4 as external standard (^{31}P NMR). Assignments of NMR peaks are given according to standard nucleoside nomenclature. EI mass spectra, FAB mass spectra and Plasma Desorption mass spectra were recorded to gain information on the molecular weight of synthesised compounds. Oligonucleotide analogues were synthesised using the phosphoramidite methodology. Purification of 5'-*O*-DMT-ON or 5'-*O*-DMT-OFF oligonucleotide analogues was accomplished using disposable reversed phase chromatography cartridges or reversed phase HPLC when necessary. Matrix-assisted laser desorption mass spectra were obtained to verify the molecular weight and monomer composition of representative oligonucleotide samples. Capillary gel electrophoresis was performed to verify the purity of representive oligonucleotide samples.

The specific descriptions below are accompanied by Figures 2-41 and Tables 1-10. Unless otherwise stated in the following examples, "LNA" designates the 2'-4'-bridged variant illustrated with the forumula **Z** in Figure 2.

Preparation of LNA monomers

Example 1

3-*C*-Allyl-1,2-*O*-isopropylidene-α-*D*-ribofuranose (0A). *Method 1:* A solution of 5-*O*-*t*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-*D*-ribofuran-3-ulose (Y. Yoshimura, T. Sano, A. Matsuda and T. Ueda, *Chem. Pharm. Bull.*, 1988, **36**, 162) (17.8 g, 58.9 mmol) in anhydrous THF (980 cm^3) was stirred at 0 °C and 1 M allylmagnesium bromide in

Example 2

3-*C*-Allyl-3,5-di-*O*-benzyl-1,2-*O*-isopropylidene-α-*D*-ribofuranose (0B). A 60% suspension of sodium hydride (4.9 g, 123 mmol) in anhydrous DMF (100 cm^3) was stirred at 0 °C and a solution of furanose **0A** (9.42 g, 40.9 mmol) in anhydrous DMF (65 cm^3) was added dropwise over 45 min. The solution was stirred for 1 h at 50 °C and cooled to 0 °C. A mixture of benzyl bromide (14.5 cm^3, 121 mmol) and anhydrous DMF (14.5 cm^3) was added dropwise and the mixture was stirred at room temperature for 18 h. The reaction mixture was evaporated to dryness and a solution of the residue in dichloromethane (700 cm^3) was washed with a saturated aqueous solution of sodium hydrogencarbonate (2 x 450 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using petroleum ether/ethylacetate (9:1, v/v) as eluent to give compound **0B** as an oil (14.5 g, 86%). δ_H ($CDCl_3$) 7.39-7.21 (10H, m, Bn), 5.92 (1 H, m, 2'-H), 5.71 (1 H, d, *J* 3.8, 1-H), 5.17-5.09 (2 H, m, 3'-H_a, 3'-H_b), 4.67 (2 H, m, Bn), 4.60 (1 H, d, *J* 12.2, Bn), 4.52 (1 H, d, *J* 12.1, Bn), 4.43 (1 H, m, 4-H), 4.42 (1 H, d, *J* 3.8, 2-H), 3.73 (1 H, dd, *J* 3.2, 10.8, 5-H_a), 3.66 (1 H, dd, *J* 7.4, 10.8, 5-H_b), 2.50 (1 H, dd, *J* 7.7, 14.9, 1'-H_a), 2.39 (1 H, dd, *J* 6.5, 14.9, 1'-H_b), 1.60 (3 H, s, CH_3), 1.34 (3 H, s, CH_3). δ_C ($CDCl_3$) 138.7, 138.1 (Bn), 132.6 (C-2'), 128.3, 128.2, 127.7, 127.5, 127.4, 127.4 (Bn), 118.5 (C-3'), 112.6 ($C(CH_3)_2$), 104.1 (C-1), 86.5, 82.1, 80.4 (C-2, C-3, C-4), 73.4, 68.6 (Bn), 67.0 (C-5), 35.8 (C-1'), 26.8, 26.6 (CH_3). FAB-MS *m/z* 433 $[M+Na]^+$ (Found: C, 73.4; H, 7.4; $C_{25}H_{30}O_5$ requires C, 73.2; H, 7.4%).

Example 3

3-*C*-Allyl-1,2-di-*O*-acetyl-3,5-di-*O*-benzyl-*D*-ribofuranose (0C). A solution of furanose **0B** (12.42 g, 30.3 mmol) in 80% aqueous acetic acid (150 cm^3) was stirred at 90 °C for 3 h. The solvent was removed under reduced pressure and the residue was coevaporated with ethanol (3 x 75 cm^3), toluene (3 x 75 cm^3) and anhydrous pyridine (2 x 75 cm^3) and redissolved in anhydrous pyridine (60 cm^3). Acetic anhydride (46 cm^3) was added and the solution was stirred at room temperature for 48 h. A mixture of ice and water (300 cm^3) was added and the resulting mixture was extracted with dichloromethane (2 x 300 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 200 cm^3) and dried (Na_2SO_4). The solvent was evaporated and the residue was purified using silica gel

Example 5

1-(3-*C*-Allyl-3,5-di-*O*-benzyl-β-*D*-ribofuranosyl)thymine (2). To a stirred solution of nucleoside **1** (11.6 g, 22.3 mmol) in methanol (110 cm^3) was added sodium methoxide (3.03 g, 55.5 mmol). The reaction mixture was stirred at room temperature for 16 h and neutralised with dilute hydrochloric acid. The solvent was partly evaporated and the residue was dissolved in dichloromethane (2 x 400 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 250 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure to give **2** as a white solid material (10.1 g, 95%). δ_H ($CDCl_3$) 8.77 (1 H, br s , NH), 7.58 (1 H , d, *J* 1.2, 6-H), 7.41-7.25 (10 H, m, Bn), 6.14 (1H, m, 2''-H), 6.12 (1 H, d, *J* 7.8, 1'-H), 5.23 (1 H, m, 3''-H_a), 5.17 (1 H, br s, 3''-H_b), 4.68 (1 H, d, *J* 10.8, Bn), 4.59 (2 H, s, Bn), 4.55 (1 H, d, *J* 10.9, Bn), 4.39 (1 H, br s, 4'-H), 4.26 (1 H, dd *J* 7.8, 10.7, 2'-H), 3.84 (1 H, dd, *J* 3.1, 11.0, 5'-H_a), 3.58 (1 H, dd, *J* 1.4, 11.0, 5'-H_b), 3.04 (1 H, d, *J* 10.8, 2'-OH), 2.82-2.78 (2 H, m, 1''-H_a, 1''-H_b), 1.51 (3 H, d, *J* 1.0, CH_3). δ_C ($CDCl_3$) 163.5 (C-4), 151.1 (C-2), 137.3, 136.7 (Bn), 136.0 (C-6), 132.1 (C-2''), 128.8, 128.5, 128.3, 127.9, 127.6 (Bn), 118.4 (C-3''), 111.1 (C-5), 87.4, 82.6, 81.1, 79.3 (C-1', C-2', C-3', C-4'), 73.7, 69.8 (Bn), 64.7 (C-5'), 35.1 (C-1''), 11.9 (CH_3). (Found: C, 67.8; H, 6.1; N, 5.5. $C_{27}H_{30}N_2O_6$ requires C, 67.8; H, 6.3; N, 5.9%).

Example 6

1-(3-*C*-Allyl-3,5-di-*O*-benzyl-2-*O*-methanesulfonyl-β-*D*-ribofuranosyl)thymine (3). To a stirred solution of nucleoside **2** (3.50 g, 7.31 mmol) in anhydrous pyridine (23 cm^3) at 0 °C was added methanesulphonyl chloride (1.69 cm^3, 21.89 mmol). The reaction mixture was stirred for 1 h at room temperature, water (100 cm^3) was added and extraction was performed using dichloromethane (3 x 150 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 200 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue purified by silica gel column chromatography using dichloromethane/methanol (99:1) as eluent to give **3** as a white solid material (3.64 g, 89%). δ_H ($CDCl_3$) 8.95 (1 H, br s , NH), 7.71 (1 H , d, *J* 1.1, 6-H), 7.39-7.25 (10 H, m, Bn), 6.52 (1 H, d, *J* 8.0, 1'-H), 5.90 (1H, m, 2''-H), 5.34 (1 H, d, *J* 7.9, 2'-H), 5.20-5.09 (2 H, m, 3''-H_a, 3''-H_b), 4.91 (1 H, d, *J* 11.2, Bn), 4.68 (1 H, d, *J* 11.3, Bn), 4.64 (2 H, s, Bn), 4.33

saturated aqueous solution of sodium hydrogencarbonate (3 x 30 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was redissolved in THF (12 cm^3) and water (12 cm^3). The mixture was stirred at room temperature and sodium boronhydride (182 mg, 4.71 mmol) was added. After stirring for 1.5 h, water (25 cm^3) was added and the solution was extracted with dichloromethane (2 x 50 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 30 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (98:2, v/v) as eluent to give **5** as a white solid material (1.13 g, 49%). δ_H ($CDCl_3$) 9.29 (1 H, br s , NH), 7.47 (1 H , d, *J* 1.1, 6-H), 7.38-7.25 (10 H, m, Bn), 6.22 (1 H, d, *J* 3.4, 1'-H), 4.62 (2 H, s, Bn), 4.60 (1 H, m, 4'-H), 4.46 (2 H, s, Bn), 4.35 (1H, dd, *J* 3.4, 7.5, 2'-H), 3.83-3.73 (4 H, m, 2 x 5'-H, 2 x 2''-H), 2.67 (1 H, br s, OH), 2.07-2.01 (2 H, m, 2 x 1''-H), 1.77 (3 H, d, *J* 0.5, CH_3). δ_C ($CDCl_3$) 164.3 (C-4), 150.3 (C-2), 137.6, 137.4 (Bn, C-6), 136.7 (Bn), 128.6, 128.4, 128.2, 127.8, 127.6, 127.3, 127.1 (Bn), 108.4 (C-5), 88.0, 87.7, 81.6, 74.7 (C-1', C-2', C-3', C-4'), 73.7, 69.6 (Bn), 64.6 (C-5'), 57.7 (C-2''), 28.6 (C-1''), 12.4 (CH_3). FAB-MS *m/z* 483 $[M+H]^+$, 505 $[M+Na]^+$ (Found: C, 63.6; H, 6.2; N, 5.4. $C_{26}H_{30}N_2O_7$,0.5H_2O requires C, 63.5; H 6.4; N, 5.7%).

Example 9

***(1S,5R,6R,8R)*-5-Hydroxy-6-(hydroxymethyl)-8-(thymin-1-yl)-2,7-dioxabicyclo[3.3.0]-octane (6).** A solution of nucleoside **5** (1.08 g, 2.20 mmol) in anhydrous pyridine (5.0 cm^3) was stirred at 0 °C and a solution of *p*-toluenesulphonyl chloride (462 mg, 2.47 mmol) in anhydrous pyridine (2.0 cm^3) was added dropwise. After stirring at room temperature for 20 h and addition of a mixture of water and ice (70 cm^3), extraction was performed with dichloromethane (2 x 75 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 50 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give an intermediate which after evaporation was dissolved in anhydrous DMF (4.0 cm^3). The solution was added dropwise to a stirred suspension of 60% sodium hydride (203 mg, 4.94 mmol) in anhydrous DMF (4.0 cm^3) at 0 °C. The mixture was stirred for 18 h and water (20 cm^3) was added. After neutralisation with hydrochloric acid, dichloromethane (75 cm^3) was added. The organic phase was

113.2 (DMT), 109.3 (C-5), 88.7, 87.3, 86.9, 83.5, 81.0 (DMT, C-1', C-2', C-3', C-4'), 69.7 (C-2''), 62.1 (C-5'), 55.1 (OCH_3), 36.5 (C-1''), 12.5 (CH_3).

Example 11

(*1S,5R,6R,8R*)-5-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-6-(4,4'-dimethoxytrityloxymethyl)-8-(thymin-1-yl)-2,7-dioxabicyclo[3.3.0]nonane (8). A solution of nucleoside **7** (436 mg, 0.743 mmol) in anhydrous dichloromethane (2.2 cm^3) and diisopropylethylamine (0.62 cm^3) was stirred at room temperature and 2-cyamoethyl *N,N*-diisopropylphosphoramidochloridite (0.33 cm^3, 1.46 mmol) was added. After stirring for 1.5 h, methanol (0.4 cm^3) and ethyl acetate (5 cm^3) were added and the mixture was washed with aqueous saturated solutions of sodium hydrogencarbonate (3 x 5 cm^3) and brine (3 x 5 cm^3). The organic phase was dried (Na_2SO_4) and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane/triethylamine (97:3, v/v) as eluent, the solvents were evaporated to give an oil which was dissolved in toluene (1 cm^3) and precipitation from hexane at −30 °C yielded **8** as a solid white material (517 mg, 88%). δ_P ($CDCl_3$) 142.0, 141.9.

Example 12

1-(3,5-Di-*O*-benzyl-3-*C*-(2-hydroxyethyl)-β-*D*-ribofuranosyl)thymine (9). To a stirred solution of nucleoside **2** (1.00 g, 2.09 mmol) in THF (5.4 cm^3) and water (5.4 cm^3) was added sodium periodate (1.34 g, 6.27 mmol) and a 2.5% solution of osmium tetraoxide in *tert*-butanol (w/w, 0.265 cm^3, 19 μmol). The solution was stirred at room temperature for 45 min. Water (25 cm^3) was added and the solution was extracted with dichloromethane (2 x 50 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 30 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was redissolved in THF (5.4 cm^3) and water (5.4 cm^3). The mixture was stirred at room temperature and sodium boronhydride (79 mg, 2.08 mmol) was added. After stirring for 1.5 h, water (25 cm^3) was added and the solution was extracted with dichloromethane (2 x 50 cm^3). The organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 30 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (98:2, v/v) as eluent to give

mixture to -10 °C, acetic anhydride (10 cm^3, 98 mmol) was added dropwise under vigorous stirring. The suspension was allowed to warm to room temperature and stirring was continued for 1.5 h whereupon the reaction was quenched by addition of triethylamine (20 cm^3). The mixture was diluted with dichloromethane to 300 cm^3 and was washed with water (2 x 200 cm^3). The organic phase was evaporated, and the residue purified by flash silica-gel chromatography using a gradient of 1.0, 1.2, 1.3, 1.4, 1.5% methanol in dichloromethane (v/v, total volume 250 cm^3 each) to give nucleoside **11** (1.89 g, 84.4%) as a white solid material. δ_H ($CDCl_3$) 7.35-7.20 (11H, m, Bn, 6-H), 6.40 (1H, s, 1'-H), 4.57 (1H, s, Bn), 4.52 (1H, s, Bn), 4.46 (1H, d, *J* 11.0, Bn), 4.29 (1H, d, *J* 11.0, Bn), 4.07 (1H, dd, *J'* 0.5, 2.2, 4'-H), 3.95-3.70 (4H, m, 2''-H_a, 2''-H_b, 5'-H_a, 5'-H_b), 2.05 (1H, m, 1''-H_a), 2.42 (1H, m, 1''-H_b), 1.42 (3H, d, *J* 1.1, 5-CH_3), 0.86 (9H, s, CH_3-C-Si), 0.01 (6H, s, CH_3-Si). δ_C ($CDCl_3$) 202.6 (C-2'), 163.7 (C-4), 151.2 (C-2), 137.7, 136.6, 136.5 (Bn, C-6), 128.7, 128.5, 128.2, 128.1, 127.7, 126.4, 126.3 (Bn), 110.9 (C-5), 84.5, 81.3, 80.2 (C-1', C-3', C-4'), 73.6, 70.4 (Bn), 66.0 (C-5'), 57.6 (C-2''), 27.3 (C-1''), 25.9, 25.7, 18.2, -5.8, -5.9 (TBDMS), 11.7 (CH_3). FAB-MS *m/z* 595.14 $[M+H]^+$ (Found: C, 64.1; H, 6.9; N, 4.5; $C_{32}H_{42}O_7N_2Si$ requires C, 64.6; H, 7.1; N, 4.7%).

Example 15

(*1S,5R,6R,8R*)-1-Hydroxy-5-benzyloxy-6-benzyloxymethyl-8-(thymin-1-yl)-2,7-dioxa-bicyclo[3.3.0]octane (12). Compound **11** (1.80 g, 30.3 mmol) was dissolved in 0.5% HCl in methanol (w/w, 20 cm^3) and the mixture was stirred for 30 min at room temperature. After evaporation to dryness, the residue was dissolved in dichloro-methane (100 cm^3) and washed with a saturated aqueous solution of sodium hydrogencarbonate (2 x 40 cm^3). The organic phase was evaporated and the residue was purified by flash silica-gel chromatography eluting with 2% methanol in dichloro-methane (v/v) to yield nucleoside **12** (1.35 g, 93.5%) as a white solid material. δ_H ($CDCl_3$) 7.37-7.27 (11H, m, Bn, 6-H), 5.87 (1H, s, 1'-H), 4.71 (2H, s, Bn), 4.64 (1H, d, *J* 12.0, Bn), 4.56 (1H, d, *J* 12.0, Bn), 4.36 (1H, t, *J* 5.7, 4'-H), 4.16 (1H, m, 2''-H_a), 3.96 (1H, m, 2''-H_b), 3.74 (2H, m, 5'-H_a, 5'-H_b), 2.35-2.15 (2H, m, 1''-H_a, 1''-H_b), 1.88 (3H, s, CH_3). δ_C ($CDCl_3$) 163.7 (C-4), 151.4 (C-2), 137.8, 137.3, 136.7 (Bn, C-6), 128.5, 128.4, 128.0, 127.8, 127.5 (Bn), 109.9 (C-5), 108.6 (C-2'), 88.8, 87.1, 80.9 (C-1', C-3', C-4'), 73.6, 68.5, 68.1, 67.9 (C-5', C-2'', Bn), 30.9 (C-1''),

m, 5'-H_a, 5'-H_a), 3.41 (3H, s, CH_3-O), 3.35 (3H, s, CH_3-N^3), 2.27 (1H, m, 1''-H_a), 2.41 (1H, m, 1''-H_b), 1.93 (3H, s, 5-CH_3). δ_C ($CDCl_3$) 163.3 (C-4), 151.0 (C-2), 138.2, 137.3, 135.7 (Bn, C-6), 128.3, 128.2, 127.8, 127.6, 127.4, 126.9 (Bn), 111.8 (C-5), 108.5 (C-2'), 89.1, 84.8, 79.5 (C-1', C-3', C-4'), 73.5, 68.4, 68.2, 67.3 (Bn, C-5', C-2''), 50.8 (CH_3-O), 32.6 (C-1''), 27.9 (CH_3-N), 13.2 (CH_3). FAB-MS: *m/z* 508.88 $[M+H]^+$ (Found: C, 65.7; H, 6.9; N, 4.8; $C_{28}H_{32}O_7N_2$ requires C, 66.1; H, 6.3; N, 5.5%). Compound **15** (97 mg, 9.1%). δ_H ($CDCl_3$) 7.37-7.28 (11H, m, Bn, 6-H), 5.86 (1H, s, 1'-H), 4.72 (2H, s, Bn), 4.64 (1H, d, *J* 11.9, Bn), 4.58 (1H, d, *J* 11.9, Bn), 4.37 (1H, t, *J* 5.6, 4'-H), 4.13 (1H, m, 2''-H_a), 3.93 (1H, m, 2''-H_b), 3.75 (2H, m, 5'-H_a, 5'-H_b), 3.34 (1H, s, CH_3-N), 2.32-2.16 (2H, m, 1''-H_a, 1''-H_b), 1.93 (3H, s, CH_3). δ_C ($CDCl_3$) 163.2 (C-4), 151.9 (C-2), 137.5, 137.1, 134.0 (Bn, C-6), 128.4, 128.3, 128.1, 127.9 127.7, 127.6, 127.3 (Bn), 108.8, 108.5 (C-2', C-5), 88.7 (C-1'), 88.0, 81.0 (C-3', C-4'), 73.5, 68.3, 67.9, 67.7 (Bn, C-5', C-2''), 30.6 (C-1''), 27.8 (CH_3-N), 13.2 (CH_3). FAB-MS *m/z* 495.28 $[M+H]^+$, 517.24 $[M+Na]^+$. Compound **16** (665 mg, 62.3%). δ_H ($CDCl_3$) 7.35-7.25 (11H, m, Bn, 6-H), 6.06 (1H, s, 1'-H), 4.73 (1H, d, *J* 11.5, Bn), 4.66 (1H, d, *J* 11.3, Bn), 4.61 (1H, d, *J* 11.9, Bn), 4.55 (1H, d, *J* 12.0, Bn), 4.34 (1H, t, *J* 5.6, 4'-H), 4.20 (1H, m, 2''-H_a), 3.98 (1H, m, 2''-H_b), 3.72 (2H, m, 5'-H_a, 5'-H_b), 3.40 (3H, s, CH_3-O), 2.45-2.35 (1H, m, 1''-H_a), 2.30-2.20 (1H, m, 1''-H_b), 1.90 (3H, d, *J* 1.1, CH_3). δ_C ($CDCl_3$) 163.2 (C-4), 150.1 (C-2), 138.2, 137.9, 137.3 (Bn, C-6), 128.4, 128.2, 127.8, 127.6 127.4, 127.1 (Bn), 110.8 (C-5), 109.3 (C-2'), 89.2, 84.2, 79.6 (C-1', C-3', C-4'), 73.6, 68.5, 68.3, 67.4 (Bn, C-5', C-2''), 50.8 (CH_3-O), 32.6 (C-1''), 12.5 (CH_3). FAB-MS *m/z* 495.22 $[M+H]^+$, 517.23 $[M+Na]^+$ (Found: C, 66.2; H, 7.2; N, 4.4; $C_{27}H_{30}O_7N_2$ requires C, 65.6; H, 6.1; N, 5.7%).

Example 18

***(1S,5R,6R,8R)*-5-Hydroxy-6-hydroxymethyl-1-methoxy-8-(thymin-1-yl)-2,7-dioxabicyclo[3.3.0]octane (17).** To a solution of nucleoside **16** (1.20 g, 2.43 mmol) in methanol (10 cm^3) was added 20% palladium hydroxide over charcoal (250 mg) and the mixture was carefully degassed under reduced pressure. An atmosphere of hydrogen was applied and stirring was continued for 12 h. The catalyst was removed by filtration of the reaction mixture through a glass column (1 x 8 cm) packed with silica gel in methanol. The column was additionally washed with methanol (20 cm^3). All fractions were collected, evaporated to dryness and co-evaporated with petroleum

$[M+H]^+$, 639.23 $[M+Na]^+$ (Found: C, 66.4; H, 6.1; N, 4.2; $C_{34}H_{36}O_9N_2$ requires C, 66.2; H, 5.9; N, 4.5%).

Example 20

(*1S,5R,6R,8R*)-5-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-6-(4,4'-dimethoxytrityloxymethyl)-1-methoxy-8-(thymin-1-yl)-2,7-dioxabicyclo[3.3.0]octane (19). Compound **18** (1.2 g, 1.95 mmol) was dissolved in anhydrous dichloromethane (10 cm^3). *N,N*-Diisopropylethylamine (1.35 cm^3, 7.8 mmol) and 2-cyanoethyl-*N,N*-diisopropylphosphoramidochloridite (0.92 g, 3.9 mmol) were added under stirring at room temperature. After 72 h, the mixture was diluted to 100 cm^3 by dichloromethane and washed by a saturated aqueous solution of sodium hydrogencarbonate (50 cm^3). The organic phase was evaporated and applied to silica gel HPLC purification using a gradient of eluent B (petroleum ether:dichloromethane:ethyl acetate:pyridine; 45:45:10:0.5; v/v/v) in eluent A (petroleum ether:dichloromethane:pyridine; 50:50:0.5; v/v/v). The fractions containing the product were concentrated, co-evaporated with toluene (10 cm^3) and dried under reduced pressure. The residue was dissolved in anhydrous benzene (20 cm^3) and precipitated by addition of this solution into anhydrous petroleum ether (400 cm^3) under stirring. The resulting white solid was isolated by filtration and dried to give compound **19** (0.96 g, 60.3%). δ_P ($CDCl_3$) 142.64, 142.52. FAB-MS *m/z* 817.26 $[M+H]^+$, 839.24 $[M+Na]^+$ (Found: C, 62.8; H, 6.4; N, 6.9; $C_{43}H_{53}O_{10}N_4P$ requires C, 63.2; H, 6.5; N, 6.9%).

Example 21

1,2-*O*-Isopropylidene-3-*C*-vinyl-α-D-ribofuranose (20). A solution of 5-*O*-*t*-butyldimethylsilyl-1,2-*O*-isopropylidene-α-D-*erythro*-pent-3-ulofuranose (Y. Yoshimura, T. Sano, A. Matsuda, T. Ueda, *Chem. Pharm. Bull.*, 1988, **36**, 162) (6.05 g, 0.020 mol) in anhydrous THF (250 cm^3) was stirred at 0 °C and a 1 M solution of vinylmagnesium bromide in ether (44 cm^3, 44 mmol) was added dropwise. The reaction mixture was stirred at room temperature for 2 h, whereupon saturated aqueous ammonium chloride (200 cm^3) was added, and extraction was performed using dichloromethane (3 x 300 cm^3). The combined extract was washed with brine (3 x 250 cm^3) and dried (Na_2SO_4). The solvent was removed and the residue was redissolved in anhydrous THF (225 cm^3). To this mixture was added a 1 M solution of tetrabutylammonium fluoride in THF (22 cm^3, 22 mmol), stirring at room temperature was continued for 20 min

Example 23

1,2-Di-*O*-acetyl-3,5-di-*O*-benzyl-3-*C*-vinyl-α,β-D-ribofuranose (22). A solution of furanose **21** (4.40 g, 11.1 mmol) in 80% aqueous acetic acid (50 cm^3) was stirred at 90 °C for 8 h. The solvents were removed and the residue was coevaporated with 99% ethanol (3 x 25 cm^3), toluene (3 x 25 cm^3) and anhydrous pyridine (2 x 25 cm^3) and redissolved in anhydrous pyridine (20 cm^3). Acetic anhydride (17 cm^3) was added and the solution was stirred at room temperature for 48 h. The reaction was quenched with ice-cold water (100 cm^3) and extracted with dichloromethane (2 x 100 cm^3). The combined extract was washed with saturated aqueous sodium hydrogencarbonate (3 x 100 cm^3) and dried (Na_2SO_4). The solvent was evaporated and the residue was purified by silica gel column chromatography using petroleum ether/ethylacetate (4:1, v/v) as eluent to give furanose **22** as an oil (4.27 g, 87%, α:β ~ 1:1). δ_C ($CDCl_3$) 169.9, 169.8 (C=O), 139.0, 138.6, 138.0, 137.8 (Bn), 133.3, 132.4 (C-1'), 128.4-126.8 (Bn), 119.6, 119.5 (C-2'), 99.5, 94.0 (C-1), 85.4, 85.0, 84.3, 83.6, 77.7, 73.6, 73.5, 73.3, 70.0, 69.2, 67.5, 67.2 (C-2, C-3, C-4, C-5, Bn), 21.0, 20.9, 20.6, 20.4 (CH_3).

Example 24

1-(2-*O*-Acetyl-3,5-di-*O*-benzyl-3-*C*-vinyl-β-D-ribofuranosyl)thymine (23). To a stirred solution of compound **22** (4.24 g, 9.6 mmol) and thymine (2.43 g, 19.3 mmol) in anhydrous acetonitrile (100 cm^3) was added *N,O*-bis(trimethylsilyl)acetamide (11.9 cm^3, 48.1 mmol). The reaction mixture was stirred at reflux for 30 min. After cooling to 0 °C, trimethylsilyl triflate (3.2 cm^3, 16.4 mmol) was added dropwise and the solution was stirred for 24 h at room temperature. The reaction was quenched with cold saturated aqueous sodium hydrogencarbonate (100 cm^3) and the resulting mixture was extracted with dichloromethane (3 x 50 cm^3). The combined extract was washed with saturated aqueous sodium hydrogencarbonate (2 x 50 cm^3) and brine (2 x 50 cm^3) and dried (Na_2SO_4). The extract was evaporated under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give nucleoside **23** as a white foam (4.03 g, 83%). δ_H ($CDCl_3$) 8.78 (1H, br s, NH), 7.75 (1H, s, 6-H), 7.38-7.26 (10 H, m, Bn), 6.49 (1H, d, *J* 8.1, 1'-H), 5.99-5.88 (2H, m, 2'-H and 1''-H), 5.54-5.48 (2H, m, 2''-H_a, 2''-H_b), 4.91-4.50 (4H, m, Bn), 4.34 (1H, s, 4'-H), 3.80 (1H, m, 5'-H_a), 3.54 (1H, m, 5'-H_b), 2.11 (3H, s, $COCH_3$), 1.48 (3H, s, CH_3). δ_C ($CDCl_3$) 170.1 (C=O), 163.8

nucleoside **25** as a yellow foam (2.53 g, 84%). δ_H ($CDCl_3$) 8.92 (1H, br s, NH), 7.71 (1H, d, *J* 1.4, 6-H), 7.41-7.28 (10H, m, Bn), 6.57 (1H, d, *J* 7.8, 1'-H), 5.99-5.61 (4H, m, 2'-H, 1''-H and 2''-H_a, 2''-H_b), 4.86-4.50 (4H, m, Bn), 4.37 (1H, dd, *J* 1.5, 2.4, 4'-H), 8.82 (1H, dd, *J* 2.6, 11.0, 5'-H_a), 3.55 (1H, dd, *J* 1.2, 11.0, 5'-H_b), 3.02 (3H, s, CH_3), 1.47 (3H, d, *J* 1.1, CH_3). δ_C ($CDCl_3$) 163.7 (C-4), 151.5 (C-2), 138.7, 136.7 (Bn), 135.7 (C-6), 130.9 (C-1''), 128.8, 128.5, 128.4, 127.6, 127.0 (Bn), 121.8 (C-2''), 111.9 (C-5), 85.1 (C-1'), 84.5 (C-3'), 84.0 (C-4'), 80.7 (C-2'), 73.7 (C-5'), 69.2, 67.7 (Bn), 38.9 (CH_3), 11.8 (CH_3).

Example 27

1-(3,5-Di-*O*-benzyl-3-*C*-vinyl-β-D-arabinofuranosyl)thymine (26). A solution of nucleoside **25** (2.53 g, 4.66 mmol) in a mixture of ethanol (50 cm^3), water (50 cm^3) and 1 M aqueous sodium hydroxide (15 cm^3) was stirred under reflux for 16 h. The mixture was neutralised using dilute aqueous hydrochloric acid, the solvent was evaporated under reduced pressure, and the residue was extracted with dichloromethane (3 x 120 cm^3). The combined extract was washed with saturated aqueous sodium hydrogencarbonate (3 x 150 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1) as eluent to give **26** as a white foam (1.61 g, 74%). δ_H ($CDCl_3$) 9.89 (1H, br s, NH), 7.50 (1H, d, *J* 1.1, 6-H), 7.41-7.26 (Bn), 6.28 (1H, d, *J* 2.8, 1'-H), 6.05 (1H, dd, *J* 11.1, 17.9, 1''-H), 5.58-5.50 (2H, m, 2''-H_a, 2''-H_b), 4.98 (1H, d, *J* 9.0, 2'-OH), 4.64-4.31 (6H, m, 2'-H, 4'-H, Bn), 3.73 (2H, m, 5'-H_a, 5'-H_b), 1.73 (1H, d, *J* 0.6, CH_3). δ_C ($CDCl_3$) 165.1 (C-4), 150.5 (C-2), 138.4, 138.0, 136.7 (C-6, Bn), 130.4 (C-1''), 128.8, 128.6, 128.5, 128.1, 128.0, 127.8 (Bn), 120.6 (C-2''), 108.1 (C-5), 88.6 (C-1'), 87.9 (C-3'), 87.2 (C-4'), 73.7 (C-2'), 71.8 (C-5'), 69.7, 66.3 (Bn), 12.3 (CH_3). Found: C, 66.8; H, 6.2; N, 5.9; $C_{26}H_{28}N_2O_6$ requires C, 67.2; H, 6.1; N, 6.0.

Example 28

1-(3,5-Di-*O*-benzyl-3-*C*-hydroxymethyl-β-D-arabinofuranosyl)thymine (27). To a solution of nucleoside **26** (2.00 g, 4.31 mmol) in a mixture of THF (15 cm^3) and water (15 cm^3) was added sodium periodate (2.76 g, 12.9 mmol) and a 2.5% solution of osmium tetraoxide in *t*-butanol (w/w, 0.54 cm^3, 43 μmol). The reaction was stirred at room temperature for 18 h, quenched with water (50 cm^3), and the mixture was

hydrogencarbonate (3 x 100 cm^3) and dried (Na_2SO_4). The solvents were evaporated and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give nucleoside **28** as a white foam (2.00 g, 93%). δ_H ($CDCl_3$) 9.13 (1H, br s, NH), 7.55 (1H, d, *J* 1.4, 6-H), 7.40-7.26 (Bn), 5.99 (1H, d, *J* 2.5, 1'-H), 5.30 (1H, d, *J* 2.7, 2'-H), 4.88-4.57 (6H, m, 1''-H_a, 1''-H_b, Bn), 4.22-4.19 (1H, m, 4'-H), 3.92 (1H, dd, *J* 6.2, 10.8, 5'-H_a), 3.82 (1H, dd, *J* 3.7, 10.8, 5'-H_b), 1.91 (3H, d, *J* 1.3, CH_3). δ_C ($CDCl_3$) 163.8 (C-4), 150.3 (C-2), 137.6 (C-6), 137.5, 137.0 (Bn), 128.7, 128.6, 128.2, 128.0, 127.8, 127.3 (Bn), 109.8 (C-5), 85.7 (C-3'), 84.1 (C-1'), 83.5 (C-4'), 79.7 (C-1''), 73.9 (C-2'), 73.6 (C-5'), 68.6, 67.8 (Bn), 12.4 (CH_3). FAB *m/z* 451 $[M+H]^+$, 473 $[M+Na]^+$. Found: C, 66.3; H, 5.9; N, 6.1; $C_{25}H_{26}N_2O_6$ requires C, 66.7; H, 5.8; N, 6.2%.

Example 30

***(1R,2R,4R,5S)*-1-Hydroxy-2-hydroxymethyl-4-(thymin-1-yl)-3,6-dioxabicyclo[3.2.0]-heptane (29).** To a stirred solution of nucleoside **28** (180 mg, 0.40 mmol) in ethanol (3 cm^3) was added 10% palladium hydroxide over carbon (90 mg). The mixture was degassed several times with argon and placed under a hydrogen atmosphere. The reaction mixture was stirred at room temperature for 6 h, then filtered through celite. The filtrate was evaporated under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (96:4, v/v) as eluent to give nucleoside **29** as a white solid material (92 mg, 86%). δ_H (CD_3OD) 7.79 (1H, d, *J* 1.2, 6-H), 5.91 (1H, d, *J* 2.5, 1'-H), 4.96 (1H, d, *J* 2.5, 2'-H), 4.92 (1H, d, *J* 7.4, 1''-H_a), 4.58 (1H, dd, *J* 0.9, 7.4, 1''-H_b), 3.98 (1H, dd, *J* 7.3, 12.8, 5'-H_a), 3.87-3.82 (2H, m, 4'-H, 5'-H_b), 3.34 (2H, s, 3'-OH, 5'-OH), 1.87 (3H, d, *J* 1.3, CH_3). δ_C (CD_3OD) 166.5 (C-4), 152.1 (C-2), 140.1 (C-6), 110.1 (C-5), 91.2 (C-2'), 85.1 (C-1'), 84.0 (C-4'), 79.6 (C-3'), 78.6 (C-1''), 61.1 (C-5'), 12.3 (CH_3).

Example 31

***(1R,2R,4R,5S)*-1-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-2-(4,4'-dimethoxytrityloxymethyl)-4-(thymin-1-yl)-3,6-dioxabicyclo[3.2.0]heptane (30).** To a solution of diol **29** (250 mg, 0.925 mmol) in anhydrous pyridine (4 cm^3) was added 4,4'-dimethoxytrityl chloride (376 mg, 1.11 mmol) and the mixture was stirred at room temperature for 18 h. The reaction was quenched with methanol (1.5 cm^3) and the mixture was evaporated under reduced pressure. A solution of the residue in

Example 33

4-*C*-(Acetoxymethyl)-3,5-di-*O*-benzyl-1,2-*O*-isopropylidene-α-*D*-ribofuranose (32). To a solution of furanose **31** (913 mg, 2.28 mmol) in anhydrous pyridine (4.5 cm^3) was dropwise added acetic anhydride (1.08 cm^3, 11.4 mmol) and the reaction mixture was stirred at room temperature for 3 h. The reaction was quenched by addition of ice-cold water (50 cm^3) and extraction was performed with dichloromethane (3 x 50 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (2 x 50 cm^3), dried (Na_2SO_4) and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane as eluent to give compound **32** as a clear oil (911 mg, 90%). δ_H ($CDCl_3$) 7.34-7.25 (10 H, m, Bn), 5.77 (1 H, d, *J* 3.6, 1-H), 4.78-4.27 (8 H, m, Bn, H-5_a, H-5_b, H-3, H-2), 3.58 (1 H, d, *J* 10.3, H-1'$_a$), 3.48 (1 H, d, *J* 10.5, H-1'$_b$), 2.04 (3 H, s, $COCH_3$), 1.64 (3 H, s, CH_3), 1.34 (3 H, s, CH_3). δ_C ($CDCl_3$) 171.1 (C=O), 138.2, 137.9, 128.6, 128.1, 128.0, 128.0, 127,8 (Bn), 114.0 ($C(CH_3)_2$), 104.5 (C-1), 85.4 (C-4), 79.3, 78.6 (C-2, C-3), 73.7, 72.7, 71.2 (Bn, C-5), 64.9 (C-1'), 26.7, 26.3 ($C(CH_3)_2$), 21.0 ($COCH_3$). Found: C, 67.0; H, 6.5; $C_{25}H_{30}O_7$,1/4H_2O requires C, 67.2; H, 6.9%.

Example 34

4-*C*-(Acetoxymethyl)-1,2-di-*O*-acetyl-3,5-di-*O*-benzyl-*D*-ribofuranose (33). A solution of furanose **32** (830 mg, 1.88 mmol) in 80% acetic acid (10 cm^3) was stirred at 90 °C for 4 h. The solvent was removed under reduced pressure and the residue was coevaporated with ethanol (3 x 5 cm^3), toluene (3 x 5 cm^3) and anhydrous pyridine (3 x 5 cm^3), and was redissolved in anhydrous pyridine (3.7 cm^3). Acetic anhydride (2.85 cm^3) was added and the solution was stirred for 72 h at room temperature. The solution was poured into ice-cold water (20 cm^3) and the mixture was extracted with dichloromethane (2 x 20 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (2 x 20 cm^3), dried (Na_2SO_4) and concentrated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane as eluent to give **33** (β:α ~ 1:3) as an clear oil (789 mg, 86%). δ_C ($CDCl_3$) 171.0, 170.3, 170.0, 169.3 (C=O), 138.1, 137.6, 136.3, 128.9, 128.6, 128.2, 128.0, 128.0, 127.9, 127.7, 124.0 (Bn), 97.8, 97.8 (C-1), 87.0, 85.0, 78.9, 74.5, 74.4, 73.8, 73.6, 72.0, 71.8, 71.0, 70.9, 64.6,

hydrogencarbonate (3 x 20 cm^3) and was dried (Na_2SO_4). The solvent was removed under reduced pressure to give **35** as a white solid material (476 mg, 97%). δ_H ($CDCl_3$) 7.47 (1 H, d, *J* 1.0 6-H), 7.36-7.22 (10 H, m, Bn), 6.07 (1 H, d, *J* 3.8, 1'-H), 4.87 (1 H, d, *J* 11.7, Bn), 4.55 (1 H, d, *J* 11.7, Bn), 4.50-4.32 (4 H, m, Bn, 2'-H, 3'-H), 3.84-3.53 (4 H, m, 5'-H_a, 5'-H_b, 1''-H_a, 1''-H_b), 1.50 (3 H, d, *J* 1.1, CH_3). δ_C ($CDCl_3$) 164.3 (C-4), 151.3 (C-2), 137.6 (C-6) 136.4, 136.3, 128.8, 128.6, 128.4, 128.3, 127,9 (Bn), 111.1 (C-5), 91.1, 91.0, 88.1 (C-1', C-3', C-4'), 77.4 (C-2'), 74.8, 73.8, 71.4, 63,2 (Bn, C-5', C-1''), 12.0 (CH_3). FAB-MS *m/z* 491 $[M+Na]^+$. Found: C, 63.4; H, 6.0; N, 5.5; $C_{25}H_{28}N_2O_7$,1/4H_2O requires C, 63.5; H, 6.1; N, 5.9%.

Example 37

Intermediate 35A. A solution of nucleoside **35** (225 mg, 0.48 mmol) in anhydrous pyridine (1.3 cm^3) was stirred at 0 °C and *p*-toluenesulphonyl chloride (118 mg, 0.62 mmol) was added in small portions. The solution was stirred at room temperature for 16 h and additional *p*-toluenesulphonyl chloride (36 mg, 0.19 mmol) was added. After stirring for another 4 h and addition of ice-cold water (15 cm^3), extraction was performed with dichloromethane (2 x 15 cm^3). The combined organic phase was washed with saturated aqueous sodium hydrogencarbonate (3 x 15 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give a intermediate **35A** (140 mg) which was used without further purification in the next step.

Example 38

(*1S,3R,4R,7S*)-7-Benzyloxy-1-benzyloxymethyl-3-(thymin-1-yl)-2,5-dioxabicyclo-[2.2.1]heptane (36). Intermediate **35A** (159 mg) was dissolved in anhydrous DMF (0.8 cm^3). The solution was added dropwise to a stirred suspension of 60% sodium hydride in mineral oil (w/w, 32 mg, 0.80 mmol) in anhydrous DMF (0.8 cm^3) at 0 °C. The mixture was stirred at room temperature for 72 h and then concentrated under reduced pressure. The residue was dissolved in dichloromethane (10 cm^3), washed with saturated aqueous sodium hydrogencarbonate (3 x 5 cm^3) and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give the bicyclic nucleoside **36** as a white solid material (65.7 mg, 57%). δ_H

DMT), 5.56 (1H, s, 1'-H), 4.53 (1H, br s, 2'-H), 4.31 (1H, m, 3'-H), 4.04-3.75 (9H, m, 1''-H_a, 1''-H_b, 3'-OH, OCH_3), 3.50 (2H, br s, 5'-H_a, 5'-H_b), 1.65 (3H, s, CH_3). $\delta_C(CDCl_3)$ 164.47 (C-4), 158.66 (DMT), 150.13 (C-2), 144.56, 135.46, 135.35, 134.78, 130.10, 129.14, 128.03, 127.79, 127.05 (C-6, DMT), 113.32, 113.14 (DMT), 110.36 (C-5), 89.17, 88.16, 87.05 (C-1', C-4', DMT), 79.36, 71.81, 70.25, 58.38 (C-2', C-3', C-5', C-1''), 55.22 (OCH_3), 12.57 (CH_3). FAB-MS *m/z* 595 $[M+Na]^+$, 573 $[M+H]^+$.

Example 41

(*1R,3R,4R,7S*)-7-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-1-(4,4'-dimethoxytrityloxymethyl)-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane (39). To a solution of nucleoside **38** (2.21 g, 3.86 mmol) in anhydrous dichloromethane (6 cm^3) at room temperature was added *N,N*-diisopropylethylamine (4 cm^3) and 2-cyanoethyl *N,N*-diisopropylphosphoramidochloridite (1 cm^3, 4.48 mmol) and stirring was continued for 1 h. MeOH (2 cm^3) was added, and the mixture was diluted with ethyl acetate (10 cm^3) and washed successively with saturated aqueous solutions of sodium hydrogencarbonate (3 x 5 cm^3) and brine (3 x 5 cm^3) and was dried (Na_2SO_4). The solvent was evaporated under reduced pressure, and the residue was purified by basic alumina column chromatography with dichloromethane/methanol (99:1, v/v) as eluent to give **39** as a white foam. This residue was dissolved in dichloromethane (2 cm^3) and the product was precipitated from petroleum ether (100 cm^3, cooled to -30°C) under vigorous stirring. The precipitate was collected by filtration, and was dried to give nucleoside **39** as a white solid material (2.1 g, 70%). $\delta_P(CDCl_3)$ 149.06, 148.74. FAB-MS *m/z* 795 $[M+Na]^+$, 773 $[M+H]^+$.

Example 42

1-(2-*O*-Acetyl-4-*C*-acetoxymethyl-3,5-di-*O*-benzyl-β-D-ribofuranosyl)uracil (40). To a stirred solution of the anomeric mixture **33** (3.0 g, 6.17 mmol) and uracil (1.04 g, 9.26 mmol) in anhydrous acetonitrile (65 cm^3) was added *N,O*-bis(trimethylsilyl)acetamide (9.16 cm^3, 37.0 mmol). The reaction mixture was stirred for 1 h at room temperature and cooled to 0°C. Trimethylsilyl triflate (1.8 cm^3, 10.0 mmol) was added dropwise and the solution was stirred at 60°C for 2 h. The reaction was quenched by addition of a saturated aqueous solution of sodium hydrogencarbonate (10 cm^3) at 0°C and extraction was performed with dichloromethane (3 x 20 cm^3). The combined

Example 44

Intermediate 42. A solution of nucleoside **41** (1.38 g, 3.0 mmol), anhydrous pyridine (2 cm^3) and anhydrous dichloromethane (6 cm^3) was stirred at -10°C and *p*-toluenesulfonyl chloride (0.648 g, 3.4 mmol) was added in small portions during 1 h. The solution was stirred at -10°C for 3 h. The reaction was quenched by addition of ice-cold water (10 cm^3) and the mixture was extracted with dichloromethane (3 x 50 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 20 cm^3) and was dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give intermediate **42** (0.9 g) which was used without further purification in the next step.

Example 45

***(1S,3R,4R,7S)*-7-Benzyloxy-1-benzyloxymethyl-3-(uracil-1-yl)-2,5-dioxabicyclo[2.2.1]-heptane (43).** Compound **42** (0.7 g) was dissolved in anhydrous DMF (3 cm^3) and a 60% suspension of sodium hydride (w/w, 0.096 g, 24 mmol) was added in four portions during 10 min at 0°C, and the reaction mixture was stirred at room temperature for 12 h. The reaction was quenched with methanol (10 cm^3), and the solvents were removed under reduced pressure. The residue was dissolved in dichloromethane (20 cm^3), washed with saturated aqueous sodium hydrogencarbonate (3 x 6 cm^3) and was dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/ethanol (99:1, v/v) as eluent to give nucleoside **43** (0.30 g, 60%). δ_H ($CDCl_3$) 9.21 (1H, br s, NH), 7.70 (1H, d, *J* 8.2, 6-H), 7.37-7.24 (10H, m, Bn), 5.65 (1H, s, 1'-H), 5.52 (1H, d, *J* 8.2, 5-H), 4.68-4.45 (5H, m, 2'-H, Bn), 4.02-3.55 (5H, m, 3'-H, 5'-H_a, 1''-H_a, 5'-H_b, 1''-H_b). δ_C ($CDCl_3$) 163.33 (C-4), 149.73 (C-2), 139.18 (C-6), 137.46, 136.81, 128.58, 128.54, 128.21, 128.10, 127.79, 127.53 (Bn), 101.66 (C-5), 87.49, 87.33 (C-1', C-4'), 76.53, 75.71, 73.77, 72.33, 72.00, 64.35 (C-2', C-3', C-5', C-1'', Bn). FAB-MS *m/z* 459 $[M+Na]^+$.

Example 46

***(1S,3R,4R,7S)*-7-Hydroxy-1-hydroxymethyl-3-(uracil-1-yl)-2,5-dioxabicyclo[2.2.1]-heptane (44).** To a solution of compound **43** (0.35 g, 0.8 mmol) in absolute ethanol (2 cm^3) was added 20% palladium hydroxide over carbon (0.37 g) and the mixture was

temperature was added *N,N*-diisopropylethylamine (0.1 cm^3) and 2-cyanoethyl *N,N*-diisopropylphosphoramidochloridite (0.07 cm^3, 0.32 mmol). After stirring for 1 h, the reaction was quenched with MeOH (2 cm^3), and the resulting mixture was diluted with ethyl acetate (5 cm^3) and washed successively with saturated aqueous solutions of sodium hydrogencarbonate (3 x 2 cm^3) and brine (3 x 2 cm^3), and was dried (Na_2SO_4). The solvent was evaporated under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give a white foam. This foam was dissolved in dichloromethane (2 cm^3) and the product was precipitated from petroleum ether (10 cm^3, cooled to -30°C) under vigorous stirring. The precipitate was collected by filtration and was dried to give compound **46** as a white solid material (0.055 g, 58%). δ_p ($CDCl_3$) 149.18, 149.02.

Example 49

9-(2-*O*-Acetyl-4-*C*-acetoxymethyl-3,5-di-*O*-benzyl-β-*D*-ribofuranosyl)-2-*N*-isobutyryl-guanine (47). To a stirred suspension of the anomeric mixture **33** (1.28 g, 5.6 mmol) and 2-*N*-isobutyrylguanine (1.8 g, 3.7 mmol) in anhydrous dichloroethane (60 cm^3) was added *N,O*-bis(trimethylsilyl)acetamide (4 cm^3, 16.2 mmol). The reaction mixture was stirred at reflux for 1 h. Trimethylsilyl triflate (1.5 mL, 8.28 mmol) was added dropwise at 0 °C and the solution was stirred at reflux for 2 h. The reaction mixture was allowed to cool to room temperature during 1.5 h. After dilution to 250 cm^3 by addition of dichloromethane, the mixture was washed with a saturated aqueous solution of sodium hydrogencarbonate (200 cm^3) and water (250 cm^3). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using 1.25% (200 cm^3) and 1.5% (750 cm^3) of methanol in dichloromethane (v/v) as eluents to give 2.10 g (87%) of a white solid that according to ^{1}H-NMR analysis consisted of three isomers (ratio: 12.5:2.5:1). The main product formed in that conditions is expected to be compound **47** (P. Garner, S. Ramakanth, *J. Org. Chem.* **1988**, 53, 1294; H. Vorbruggen, K. Krolikiewicz, B. Bennua, *Chem. Ber.* **1981**, 114, 1234). The individual isomers were not isolated and mixture was used for next step. For main product **47**: δ_H ($CDCl_3$) 12.25 (br s, NHCO), 9.25 (br s, NH), 7.91 (s, 8-H) 7.39-7.26 (m, Bn), 6.07 (d, *J* 4.6, 1'-H), 5.80 (dd, *J* 5.8, *J* 4.7, 2'-H), 4.72 (d, *J* 5.9, 3'-H), 4.59-4.43 (m, Bn, 1''-H_a), 4.16 (d, *J* 12.1, 1''-H_b), 3.70 (d, *J* 10.1, 5'-H_a), 3.58 (d, *J* 10.1, 5'-H_b), 2.65 (m, CHCO), 2.05 (s, $COCH_3$), 2.01 (s, $COCH_3$), 1.22 (d, *J* 6.7, CH_3CH), 1.20 (d, *J* 7.0, CH_3CH). δ_C ($CDCl_3$) 178.3 (COCH), 170.6, 179.8

and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane/methanol as eluent (1-2%, v/v) to give intermediate **49** (980 mg). After elution of compound **49** from the column, the starting mixture containing **48** (510 mg) was eluted using 8% methanol in dichloromethane (v/v) as eluent. This material was concentrated, dried under reduced pressure and treated in the same manner as described above to give additionally 252 mg of the intermediate. The intermediate (1.23 g) was purified by silica gel HPLC (PrepPak Cartridge packed by Porasil, 15-20 μm, 125A, flow rate 60 cm^3/min, eluent 0-4% of methanol in dichloromethane (v/v), 120 min). Fractions containing intermediate **49** were pooled and concentrated to give white solid (1.04 g). According to ^{1}H-NMR it consisted of two main products, namely 1''-*O* and 2'-*O* monotosylated derivatives in a ratio of ~ 2:1. FAB-MS *m/z* 718 $[M+H]^+$. Found C, 60.4; H, 5.8; N, 9.3; $C_{36}H_{39}N_5O_9S$ requires C, 60.2; H, 5.5; N, 9.8%.

Example 52

***(1S,3R,4R,7S)*-7-Benzyloxy-1-benzyloxymethyl-3-(2-*N*-isobutyrylguanin-9-yl)-2,5-dioxabicyclo[2.2.1]heptane (50).** To a solution of intermediate **49** (940 mg) in anhydrous THF (20 cm^3) was added a 60% suspension of sodium hydride (w/w, 130 mg, 3.25 mmol) and the mixture was stirred for 1h at room temperature. Acetic acid (0.25 mL) was added and the mixture was concentrated under reduced pressure. The residue was dissolved in dichloromethane (100 cm^3) and was washed with water (2 x 100 cm^3). The organic phase was separated and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using methanol/dichloromethane (1-1.5%, v/v) as eluent to give nucleoside **50** as a white solid material (451 mg, 57%). δ_H ($CDCl_3$) 12.25 (1H, br s, NHCO), 10.12 (1H, br s, NH), 7.84 (1H, s, 8-H), 7.31-7.15 (10H, m, Bn), 5.72 (1H, s, 1'-H), 4.60-4.46 (5H, m, Bn, 2'-H), 4.14 (1H, s, 3'-H), 4.02 (1H, d, *J* 7.9, 1''-H_a), 3.85 (1H, d, *J* 7.9, 1''-H_b), 3.78 (2H, s, 5'-H), 2.81 (1H, m, CHCO), 1.24 (3H, d, *J* 6.8, CH_3CH), 1.22 (3H, d, *J* 6.4, CH_3CH). δ_C ($CDCl_3$) 179.5 (COCH), 155.6, 148.1, 147.3 (guanine), 137.3, 136.9, 136.0 (guanine, Bn), 128.4, 128.3, 127.9, 127.8, 127.5, 127.4 (Bn), 121.2 (guanine), 87.1, 86.2 (C-1', C-4'), 77.0 (C-3'), 73.6, 72.5, 72.1 (Bn, C-2', C-5'), 64.9 (C-1''), 36.1 (COCH), 19.0 (CH_3CH), 18.9 (CH_3CH). FAB-MS *m/z* 546 $[M+H]^+$. Found: C, 63.3; H, 5.9; N, 12.5; $C_{29}H_{30}N_5O_6$ requires C, 64.0; H, 5.6; N, 12.9%.

Example 54

(*1R,3R,4R,7S*)-1-(4,4'-Dimethoxytrityloxymethyl)-7-hydroxy-3-(2-*N*-isobutyrylguanin-9-yl)-2,5-dioxabicyclo[2.2.1]heptane (52). A mixture of compound **51** (440 mg, 1.21 mmol) and 4,4'-dimethoxytrityl chloride (573 mg, 1.69 mmol) was dissolved in anhydrous pyridine (7 cm^3) and was stirred at room temperature for 4 h. The mixture was evaporated under reduced pressure to give an oil. Extraction was performed in a system of dichloromethane/water (1:1, v/v, 40 cm^3). The organic phase was separated and concentrated to give a solution in a minimal volume of dichloromethane containing 0.5% of pyridine (v/v) which was applied to a silica gel column equilibrated by the same solvent. The product was eluted in gradient concentrations of methanol (0.6 - 2%, v/v) in dichloromethane containing 0.5% of pyridine (v/v) to give compound **52** as a white solid material (695 mg, 86%). δ_H ($CDCl_3$) 12.17 (1H, br s, NHCO), 10.09 (1H, br s, NH), 7.87 (1H, s, 8-H), 7.42-6.72 (13H, m, DMT), 5.69 (1H, s, 1'-H), 4.59 (1H, s, 2'-H), 4.50 (1H, s, 3'-H), 3.98 (1H, d, *J* 8.1, 1''-H_a), 3.69-3.39 (9H, m, DMT, 5'-H, 1''-H_b), 2.72 (1H, m, CHCO), 1.17 (6H, d, *J* 6.8, CH_3CH). δ_C ($CDCl_3$) 179.8 (COCH), 158.8, 144.5, 135.6, 135.5, 130.1, 128.1, 127.7, 126.9, 113.2 (DMT), 155.8, 147.9, 147.5, 137.0, 120.8 (guanine), 87.6, 86.4, 86.1 (C-1', C-4', DMT), 79.7 (C-3'), 72.6, 71.4 (C-2', C-5'), 59.8 (C-1''), 55.2 (DMT), 36.1 (COCH), 19.1, 18.8 (CH_3CH). FAB-MS *m/z* 668 $[M+H]^+$.

Example 55

(*1R,3R,4R,7S*)-7-(2-Cyanoethoxy(diisopropylamino)phosphinoxy)-1-(4,4'-dimethoxytrityloxymethyl)-3-(2-*N*-isopropyonylguanin-9-yl)-2,5-dioxabicyclo[2.2.1]heptane (53). Compound **52** (670 mg, 1.0 mmol) was at room temperature dissolved in anhydrous dichloromethane (5 cm^3) containing *N,N*-diisopropylethylamine (0.38 cm^3, 4 mmol). 2-Cyanoethyl *N,N*-diisopropylphosphoramidochloridite (0.36 cm^3, 2.0 mmol) was added drop-wise with stirring. After 5 h, methanol (2 cm^3) was added and the mixture was diluted to 100 cm^3 by addition of dichloromethane and washed with a saturated aqueous solution of sodium hydrocarbonate (50 cm^3). The organic phase was separated and the solvent was removed by evaporation under reduced pressure. The residue was dissolved in the minimun amount of dichloromethane/petroleum ether (1:1, v/v) containing 0.5% pyridine (v/v) and was applied to a column packed with silica gel equilibrated by the same solvent mixture. The column was washed by dichloromethane/petroleum/pyridine (75:25:0.5, v/v/v, 250 cm^3) and the product was

temperature for 10 min and then neutralised with 20% aqueous hydrochloric acid. The solvent was partly evaporated and the residue was extracted with dichloromethane (3 x 50 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 20 cm^3) and was dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (98.5:1.5, v/v) as eluent to give compound **55** as a white solid material (1.6 g, 54%). δ_H ($CDCl_3$) 9.95 (1H, br s, NH), 8.33 (1H, d, *J* 7.4, 6-H), 7.98 (2H, m, Bz), 7.60-7.12 (14H, m, Bn, Bz, 5-H), 6.17 (1H, d, *J* 1.6, 1'-H), 4.78 (1H, d, *J* 11.8, Bn), 4.48-4.27 (5H, m, Bn, 2'-H, 3'-H), 3.85 (1H, d, *J* 11.8, 5'-H_a), 3.66-3.61 (2H, m, 5'-H_b, 1''-H_a), 3.47 (1H, d, *J* 10.4, 1''-H_b). δ_C ($CDCl_3$) 167.5, 162.31 (C-4, C=O), 155.36 (C-2), 145.34 (C-6), 137.49, 137.08, 133.09, 133.01, 128.94, 128.67, 128.48, 128.30, 128.01, 127.90, 127.80 (Bn, Bz), 96.53 (C-5), 93.97, 89.35 (C-1', C-4'), 76.06, 75.28, 73.70, 72.76, 70.26, 62.44 (C-2', C-3', Bn, C-5', C-1''). FAB-MS *m/z* 558 $[M+H]^+$.

Example 58

Intermediate 56. A solution of nucleoside **55** (2.2 g, 3.94 mmol) in anhydrous tetrahydrofuran (60 cm^3) was stirred at -20 °C and a suspension of 60% sodium hydride in mineral oil (w/w, 0.252 g, 6.30 mmol) was added in seven portions during 45 min. The solution was stirred for 15 min at -20 °C followed by addition of *p*-toluenesulfonyl chloride (0.901 g, 4.73 mmol) in small portions. The solution was stirred for 4 h at -20 °C. Additional sodium hydride (0.252 g, 6.30 mmol) and *p*-toluenesulfonyl chloride (0.751 g, 3.93 mmol) was added. The reaction mixture was kept at -20 °C for 48 h. The reaction was quenched by addition of ice-cold water (50 cm^3) whereupon extraction was performed with dichloromethane (3x 60 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 20 cm^3) and dried (Na_2SO_4). The solvent was evaporated under reduced pressure and the residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give the intermediate **56** (1.80 g).

Example 59

***(1S,3R,4R,7S)*-7-Benzyloxy-1-benzyloxymethyl-3-(4-*N*-benzoylcytosin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane (57).** Intermediate **56** (1.80 g) was dissolved in anhydrous DMF (30.0 cm^3) and a 60% suspension of sodium hydride in mineral oil (w/w, 0.16 g, 3.9

Example 61

Intermediate 57B. To nucleoside **57A** (0.030 g, 0.11 mmol) suspended in anhydrous pyridine (2.0 cm^3) was added trimethylsilyl chloride (0.14 cm^3, 1.17 mmol) and stirring was continued for 1 h at room temperature. Benzoyl chloride (0.07 cm^3, 0.58 mmol) was added at 0 °C and the mixture was stirred for 2 h at room temperature. After cooling the reaction mixture to 0 °C, water (3.0 cm^3) was added. After stirring for 5 min, an aqueous solution of ammonia (1.5 cm^3, 32%, w/w) was added and stirring was continued for 30 min at room temperature. The mixture was evaporated under reduced pressure, and the residue was purified by silica gel column chromatography using dichloromethane/methanol (97.5:2.5, v/v) as eluent to give intermediate **57B** as white solid material (0.062 g).

Example 62

***(1R,3R,4R,7S)*-1-(4,4'-Dimethoxytrityloxymethyl)-7-hydroxy-3-(4-*N*-benzoylcytosine-1-yl)-2,5-dioxabicyclo[2.2.1]heptane (57C).** To a solution of intermediate **57B** (0.042 g, 0.11 mmol) in anhydrous pyridine (1.5 cm^3) was added 4,4'-dimethoxytrityl chloride (0.06 g, 0.17 mmol). The reaction mixture was stirred at room temperature for 3.5 h, cooled to 0 °C, and a saturated aqueous solution of sodium hydrogencarbonate (20 cm^3) was added. Extraction was performed using dichloromethane (3 x 10 cm^3). The combined organic phase was dried (Na_2SO_4) and evaporated to dryness under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane/methanol/pyridine (98.0:1.5:0.5, v/v/v) as eluent to give nucleoside **57C** as a white solid material (0.031g, ~63% from **57A**). δ_H (C_5D_5N) 12.32 (1H, br s, NHCO), 8.75-7.06 (20H, m, DMT, Bz, H-5, H-6), 6.24 (1H, s, 1'-H), 5.11 (1-H, s, 2'-H), 4.90 (1H, s, 3'-H), 4.38 (1H, d, *J* 7.6, 1''-H_a), 4.10 (1H, d, *J* 7.6, 1''-H_b), 4.02 (1H, d, *J* 10.6, 5'-H_a), 3.87 (1H, d, *J* 10.6, 5'-H_b), 3.77, 3.76 (2 x 3H, 2 x s, 2 x OCH_3). δ_C (C_5D_5N) 169.00 (NHCO), 164.24 (C-2), 159.39 (DMT), 150.5, 145.62 (DMT), 144.31, 132.89, 130.82, 130.72, 129.09, 128.89, 128.60, 113.96 (DMT), 96.96 , 89.01, 87.18, 79.91, 72.56, 70.25 (C-5, C-1', C-4', C-2', C-1'',C-3'), 59.51 (C-5'), 55.33 (OCH_3). FAB-MS *m/z* 662 $[M+H]^+$.

128.66, 128.53, 128.41, 128.38, 128.18, 128.06, 127.91, 127.88, 127.79, 127.63, 123.26 (Bz, Bn, C-5), 86.38 (C-1'), 86.25 (C-4'), 77.74, 74.74, 74.44, 73.48 (C-2', C-3', 2 x Bn), 70.11 (C-1''), 63.42 (C-5'), 20.70, 20.54 ($COCH_3$). FAB-MS *m/z* 666 $[M+H]^+$.

Example 65

9-(3,5-Di-*O*-benzyl-4-*C*-hydroxymethyl-β-*D*-ribofuranosyl)-6-*N*-benzoyladenine (59). To a stirred solution of nucleoside **58** (4.18 g, 6.28 mmol) in methanol (50 cm^3) was added sodium methoxide (0.75 g, 13.8 mmol) at 0 °C. The reaction mixture was stirred for 2 h, and ice was added. The mixture was neutralised using a 20% aqueous solution of HCl. Extraction was performed using dichloromethane (3 x 75 cm^3), the organic phase was separated, dried (Na_2SO_4) and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane/-methanol (98.5:1.5, v/v) as eluent to give nucleoside **59** as a white solid material (2.68 g, 73%). δ_H ($CDCl_3$) 9.42 (1H, br s, NH), 8.58 (1H, s, H-8), 8.16 (1H, s, 2-H), 7.96 (2H, d, *J* 7.2, Bz), 7.52-7.08 (13H, m, Bn, Bz), 6.18 (1H, d, *J* 2.5, 1'-H), 4.85-4.38 (4H, m, Bn, 2'-H, 3'-H), 4.33 (2H, s, Bn) 3.90 (1H, d, *J* 11.9, 1''-H_a), 3.71 (1H, d, *J* 11.8, 1''-H_b), 3.50-3.39 (2H, m, 5-H). δ_C ($CDCl_3$) 164.98 (NHCO), 152.19 (C-6), 151.00 (C-2), 149.34 (C-4), 142.28 (C-8), 137.32, 137.25, 133.46, 132.70, 128.69, 128.49, 128.40, 128.11, 128.03, 127.94, 127.83, 127.62, (Bz, Bn), 122.92 (C-5), 90.94, 88.75 (C-1', C-4'), 77.65, 74.08, 73.44, 73.20, 71.12, 62.39 (C-1'', C-5', C-2', C-3', 2 x Bn). FAB-MS *m/z* 582 $[M+H]^+$. Found: C, 65.6; H, 5.5; N, 11.7; $C_{32}H_{31}N_5O_6$ requires C, 66.1; H, 5.4; N, 12.0%.

Example 66

Intermediate 60. A solution of nucleoside **59** (2.43 g, 4.18 mmol) in anhydrous tetrahydrofuran (25 cm^3) was stirred at -20 °C and a 60% suspension of sodium hydride in mineral oil (w/w, 0.28 g, 7.0 mmol) was added in four portions during 30 min. After stirring for 1 h, *p*-toluenesulfonyl chloride (1.34 g, 7.0 mmol) was added in small portions. The mixture was stirred at -10 °C for 15 h. Ice-cold water (50 cm^3) was added and extraction was performed with dichloromethane (3 x 50 cm^3). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (2 x 25 cm^3), dried (Na_2SO_4) and evaporated under reduced

methanol (92:8, v/v) as eluent to give nucleoside **61A** as a white solid material (0.332 g, 84%). δ_H ($(CD_3)_2SO$) 8.22 (1H, s, 8-H), 8.15 (1H, s, 2-H), 7.33 (2H, s, NH_2), 5.89 (1H, s, 1'-H), 5.83 (1H, d, *J* 4.2, 3'-OH), 5.14 (1H, t, *J* 5.9, 5'-OH), 4.14 (1H, s, 2'-H), 4.25 (1H, d, *J* 4.2, 3'-H), 3.92 (1H, d, *J* 7.8, 1''-H_a), 3.81-3.41 (3H, m, 5'-H_a, 5'-H_b, 1''-H_b). δ_C ($(CD_3)_2SO$) 155.90 (C-6), 152.64 (C-2), 148.35 (C-4), 137.72 (C-8), 118.94 (C-5), 88.48, 85.17 (C-1', C-4'), 79.09, 71.34, 69.83, 56.51 (C-2', C-3', C-1'', C-5'). FAB-MS *m/z* 280 $[M+H]^+$.

Example 69

(*1S,3R,4R,7S*)-7-Hydroxy-1-hydroxymethyl-3-(6-*N*-benzoyladenin-9-yl)-2,5-dioxabicyclo[2.2.1]heptane (61B). To a stirred solution of nucleoside **61A** (0.32 g, 1.15 mmol) in anhydrous pyridine (1 cm^3) was added trimethylsilyl chloride (0.73 cm^3, 5.73 mmol) and the mixture was stirred at room temperature for 20 min. Benzoyl chloride (0.67 cm^3, 5.73 mmol) was added at 0 °C, and the reaction mixture was stirred at room temperature for 2 h. The reaction mixture was cooled to 0 °C and ice-cold water (15.0 cm3) was added. After stirring for 5 min, a 32% (w/w) aqueous solution of ammonia (1.5 cm^3) was added and the mixture was stirred for 30 min. The mixture was evaporated to dryness and the residue was dissolved in water (25 cm^3). After evaporation of the mixture under reduced pressure, the residue was purified by silica gel chromatography using dichloromethane/methanol (97:3, v/v) as eluent to give nucleoside **61B** as a white solid material (0.55 g).
FAB-MS *m/z* 384 $[M+H]^+$.

Example 70

(*1R,3R,4R,7S*)-7-Hydroxy-1-(4,4'-dimethoxytrityloxymethyl)-3-(6-*N*-benzoyladenin-9-yl)-2,5-dioxabicyclo[2.2.1]heptane (61C). To a stirred solution of compound **61B** (0.50 g) in anhydrous pyridine (20 cm^3) was added 4,4'-dimethoxytrityl chloride (0.71 g, 2.09 mmol) and 4-*N,N*-dimethylaminopyridine (DMAP) (0.1 g). After stirring for 2 h at room temperature and for 1 h at 50 °C, the reaction mixture was cooled to 0 °C and a saturated aqueous solution of sodium hydrogencarbonate (100 cm^3) was added. After extraction using dichloromethane (3 x 50 cm^3), the combined organic phase was dried (Na_2SO_4) and evaporated under reduced pressure. The residue was purified by silica gel column chromatography eluting with dichloromethane/methanol/pyridine (98.0:1.5:0.5) to give nucleoside **61C** as a white solid material (0.36 g, ~50% from

Example 72

1-(2,3-*O*-isopropylidene-4-*C*-(4-toluenesulphonyloxymethyl)-β-D-ribofuranosyl)uridine (62). To a stirred solution of 1-(2,3-*O*-isopropylidene-4'-*C*-hydroxymethyl-β-D-ribofuranosyl)uridine (2.0 g, 6.4 mmol) (R. Youssefyeh, D. Tegg, J. P. H. Verheyden, G. H. Jones and J. G. Moffat, *Tetrahedron Lett.*, 1977, 5, 435; G. H. Jones, M. Taniguchi, D. Tegg and J. G. Moffat, *J. Org. Chem.*, 1979, 44, 1309) in anhydrous pyridine (28 cm^3) was added *p*-toluenesulfonyl chloride (1.46 g, 7.3 mmol) dissolved in anhydrous pyridine (10 cm^3) at -30 °C. After 30 min, the reaction mixture was allowed to reach room temperature and stirring was continued at room temperature for 12 h. The reaction was quenched with methanol (4 cm^3), silica gel (2g) was added and the solvent was removed under reduced pressure. The residue was purified by silica gel column chromatography using a gradient of 0-3% methanol in dichloromethane (v/v) as eluent to give nucleoside **62** as a pale reddish solid material (1.8 g, 60%). δ_H ($CDCl_3$) 9.80 (1H, br s, NH), 7.80 (2H, d, *J* 8.3, Ts), 7.46 (1H, d, *J* 8.1, 6-H), 7.35 (2H, d, *J* 8.01, Ts), 5.72 (1H, d, *J* 8.0, 5-H), 5.54 (1H, d, *J* 3.5, 1'-H), 5.08 (1H, dd, *J* 3.5, 6.4, 2'-H), 4.94 (1H, d, *J* 6.4, 3'-H), 4.18 (2H, s, 1''-H), 3.82-3.70 (2H, m, 5'-H), 2.45 (3H, s, Ts), 1.46, 1.29 (6 H, s, CH_3). δ_C ($CDCl_3$) 163.6 (C-4), 150.4 (C-2), 145.2 (C-6), 142.9, 132.5, 129.9, 128.0 (Ts), 114.7 (OCO), 102.6 (C-5), 94.9, 87.6, 83.9, 81.5 (C-4', C-1', C-3', C-2'), 68.7, 63.5 (C-1'', C-5'), 26.4, 24.7 (CH_3), 21.7 (Ts). FAB-MS *m/z* 469 $[M+H]^+$.

Example 73

1-(4-*C*-(*p*-Toluenesulphonyloxymethyl-β-D-ribofuranosyl)uridine (63). Nucleoside **62** (1.33 g, 2.83 mmol) was dissolved in 80% acetic acid (25 cm^3) and stirred at 80 °C for 3 h whereupon the solvent was removed under reduced pressure. The residue was coevaporated with ethanol (10 cm^3) and purified by silica gel column chromatography using a gradient of 0-2% methanol in dichloromethane (v/v) as eluent to give nucleoside **63** as a white solid material (391 mg, 33%). δ_H (CD_3OD) 7.81 (1H, d, *J* 8.1, 6-H), 7.77 (1H, d, *J* 8.4, Ts), 7.40 (2H, d, *J* 8.6, Ts), 5.74 (1H, d, *J* 6.6, 1'-H), 5.69 (1H, d, *J* 8.1, 5-H), 4.17-4.33 (2H, m, 2'-H, 3'-H), 3.67-3.62 (2H, m, 1''-H), 3.26-3.20 (2H, m, 5'-H), 2.43 (3H, s, Ts). δ_C (CD_3OD) 166.0 (C-4), 153.0 (C-2), 146.5 (C-6), 142.5, 130.9, 129,15 (Ts), 103.1 (C-5), 89.0, 87.2 (C-1', C-4'), 75.1, 72.7, 71.3, 63.8 (C-1'', C-3', C-2', C-5'), 21.6 (Ts).

in EtOAc and washed with a saturated aqueous solution of sodium hydrogencarbonate (2 × 9 cm^3) and water (9 cm^3). The aqueous phase was extracted with dichloromethane (3 x 20 cm^3). The combined organic phase was evaporated under reduced pressure and the residue was redissolved in dioxane (4 cm^3), whereupon 32% aqueous ammonia (0.7 cm^3) was added. After stirring for 3 h, the reaction mixture was evaporated under reduced pressure and coevaporated with anhydrous pyridine. The residue was dissolved in anhydrous pyridine (3.6 cm^3) and benzoyl chloride (0.42 cm^3, 3.6 mmol) was added. After stirring for 2 h, the reaction was quenched with water (1 cm^3) and the reaction mixture was evaporated under reduced pressure. The residue was then redissolved in EtOAc and washed with water (3 × 7 cm^3). The organic phase was evaporated to dryness under reduced pressure, and the residue was dissolved in pyridine/methanol/water (13:6:1, v/v/v, 14 cm^3) at 0 °C, and a 2M solution of NaOH in pyridine/methanol/water (13:6:1, v/v/v, 7 cm^3) was added. After stirring for 20 min, the reaction mixture was neutralised using a 2M solution of HCl in dioxane, and the reaction mixture was evaporated under reduced pressure. The residue was purified by silica column chromatography using dichloromethane/methanol (95:5, v/v) as eluent to give nucleoside **65** as a yellow foam (94.6 mg, 38%). δ_H (CD_3OD) 8.21 (1H, br, s), 8.02 (1H, m), 7.84-7.9 (1H, m), 7.41-7.58 (4H, m), 5.61 (1H, s), 4.36 (1H, s), 4.10 (1H, s), 3.98 (1H, d, *J* 8.0), 3.94 (2H, s), 3.78 (1H, d, *J* 7.9), 2.11 (3H, d, *J* 1.0). δ_C (CD_3OD, selected signals) 133.66, 132.90, 130.63, 129.50, 129.28, 128.65, 90.71, 88.86, 80.57, 72.47, 70.22, 57.53, 14.01. FAB-MS *m/z* 374 $[M+H]^+$.

Example 77

(*1R,3R,4R,7S*)-1-(4,4'-Dimethoxytrityloxymethyl)-3-(5-methyl-4-*N*-benzoylcytosine-1-yl)-7-*O*-(2-cyanoethoxy(diisopropylamino)phosphinoxy)-2,5-dioxabicyclo[2.2.1]heptane (66). To a stirred solution of nucleoside **65** (82 mg, 0.22 mmol) in anhydrous pyridine (1.5 cm^3) was added 4,4'-dimethoxytrityl chloride (80 mg, 0.24 mmol) and stirring was continued at room temperature for 12 h. Additional 4,4'-dimethoxytrityl chloride (80 mg, 0.24 mmol) was added, and stirring was continued for another 12 h. Methanol (0.5 cm^3) was added and the reaction mixture was evaporated under reduced pressure. The residue was subjected to silica gel column chromatography using dichloromethane/methanol/pyridine (98.5:1.0:0.5, v/v/v). The resulting intermediate (FAB-MS *m/z* 676) (50.2 mg) was coevaporated with anhydrous

s), 1.38 (3H, s). δ_C ($CDCl_3$) 164.8, 152.2, 150.4, 150.2, 142.6, 133.3, 132.9, 128.8, 128.0, 124.1, 114.7, 93.3, 90.2, 83.8, 82.5, 65.3, 62.9, 27.3, 25.1. FAB-MS: *m/z* 442 $[M+H]^+$, 464 $[M+Na]^+$.

Alternative synthesis of 67. To a solution of 2',3'-O-isopropylideneadenosine (15 g) in anhydrous pyridine (250 mL) was added trimethylsilyl chloride (15.5 mL). The reaction mixture was stirred at room temperature for 20 min and cooled to 0 °C. Benzoyl chloride (17 mL) was added drop-wise and the mixture was kept at room temperature temperature for 2-3 h. Water (50 mL) and 25 % aq. ammonium hydroxide (100 mL) was added and stirring was continued for 3 h. Then the mixture was concentrated under reduced pressure, co-evaporated with toluene (2 x 200 mL) and dichloro-methane (DCM) and saturated sodium hydrogencarbonate was added. The organic phase was evaporated to dryness to give a yellow solid. Recrystallisation from ethanol resulted in 12.5 g (ca 80 %) as a white solid intermediate material. Oxalyl chloride (4.68 mL) in dry DCM (120 mL) was cooled to -70° C. DMSO (8.5 mL) was added during intensive stirring. Later (10 min) a solution of the intermediate for which the synthesis is described above (17 g) in 10% DMSO/DCM (100 mL) added dropwise (20 min). The temperature was allowed to increase to -50° C over a period of 30 min after which the reaction was quenched with triethylamine (35 mL). To the mixture was added DCM (200 ml) which was washed with water (3 x 200 mL). The intermediate was concentrated *in vacuo* , co-evaporated with dioxane, and redissolved in dioxane (120 mL). Formaldehyde (37 %) and 2 M aq. sodium hydroxide (40 mL) was added and the reaction mixture was stirred for 1 h. The mixture was neutralised with acetic acid (6 mL) and DCM (400 ml) and saturated sodium hydrogencarbonate (400 mL) were added. The organic phase was concentrated. The product **67** was purified by column chromatography (silica gel, 1.5 - 5.0 % methanol/ DCM). Yield 8.5 g (46 %) of **67**. Data were as stated earlier in this example.

Example 79

9-(2,3-*O*-Isopropylidene-4-(p-toluenesulfonyloxymethyl)-β-*D*-ribofuranosyl)-6-*N*-benzoyl-adenine (68) and 9-(4-hydroxymethyl-2,3-*O*-isopropylidene-5-*O*-(p-toluenesulfonyl)-β-*D*-ribofuranosyl)-6-*N*-benzoyladenine. A mixture of compound **67** (1.95 g, 4.42 mmol) and p-toluenesulfonyl chloride (1.26 g, 6.63 mmol) was dissolved in 10 mL of anhydrous pyridine at 0 °C. The reaction mixture was stirred for 4 h and then diluted

mixture was allowed to warm to room temperature, diluted by dichloromethane (100 mL) and washed by water (2 x 100 mL). The organic phase was concentrated, and the residue was purified by the use of preperative HPLC (PrepPak cartridge, Porasil 15-20 µm 125 Å; eluent: 0-3% of methanol in dichloromethane (v/v) in 120 min; flow rate: 60 ml/min). Concentration *in vacuo* yielded 870 mg (78%) of compound **70** as a white solid material. δ_H ($CDCl_3$) 8.65 (1H, s), 8.03(2H, m), 8.00 (1H, s), 7.83 (2H, d, *J*8.4), 7.58 (1H, m), 7.49 (2H, m), 7.34 (2H, d, *J*8.4), 5.87 (1H, s), 5.70 (1H, d, *J*6.2), 4.68 (1H, d, *J*6.2), 4.59 (1H, d, *J*10.8), 4.31 (1H, d, *J*11.0), 3.91 (2H, s), 2.45 (3H, s), 1.03-0.84 (28H, m). δ_C ($CDCl_3$) 164.9, 152.2, 150.5, 150.0, 144.7, 142.9, 133.5, 132.9, 132.8, 129.7, 128.8, 128.1, 128.0, 123.6, 90.3, 85.3, 76.0, 75.0, 68.7, 65.2, 21.6, 17.5, 17.4, 17.2, 17.1, 17.0,16.9, 13.1, 13.0, 12.5,12.4. FAB-MS: *m/z* 798 $[M+H]^+$

Example 82

9-(2-*O*,4-*C*-Methylene-3,5-*O*-(tetraisopropyldisiloxa-1,3-diyl)-β-*D*-ribofuranosyl)-6-*N*-benzoyladenine (71). A solution of compound **70** (540 mg, 0.68 mmol) in anhydrous THF (20 mL) was cooled to 0 °C and sodium hydride (130 mg of 60% suspension in mineral oil, 3.25 mmol) was added under stirring. The reaction mixture was stirred for 30 min and then neutralised by addition of 750 µL of acetic acid. Dichloromethane (50 mL) was added, the mixture was washed by a saturated aqueous solution of sodium hydrogen carbonate (2 x 50 mL) and concentrated under reduced pressure. The residue was applied to a silica gel column (2.5 x 25 cm) and the product was eluted in a gradient concentration (0.5 to 1.2 %) of methanol in dichloromethane as eluent to yield compound **71** (356 mg, 84 %) as a white foam. δ_H ($CDCl_3$) 8.77 (1H, s), 8.28 (1H, s), 8.03(2H, m), 7.59 (1H, m), 7.50 (2H, m), 6.08 (1H, s), 4.86 (1H, s), 4.56 (1H, s), 4.14 (1H, d, *J*13.2), 4.06 (1H, d, *J*7.7), 3.97 (1H, d, *J*13.2), 3.89 (1H, d, *J*7.7), 1.12-0.95 (28H, m). δ_C ($CDCl_3$) 164.8, 152.6, 150.5, 149.6, 140.7, 133.6, 132.7, 128.7, 127.9, 123.1, 89.4, 86.5, 78.9, 71.7, 71.2, 56.7, 17.3, 17.1, 17.0,16.9, 16.8, 13.3, 13.1, 12.5,12.2. FAB-MS: *m/z* 626 $[M+H]^+$

Example 83

7-Hydroxy-1-hydroxymethyl-3-(6-*N*-benzoyladenin-9-yl)-2,5-dioxabicyclo[2.2.1]-heptane (61B). Triethylamine tris-hydrofluoride (300 µL, 1.84 mmol) was added to a solution of compound **71** (420 mg, 0.067 mmol) in anhydrous THF (7 mL). The

Example 86

1-(2-Amino-2-deoxy-2-*N*,4-*C*-methylene-β-*D*-ribofuranosyl)thymine (74). To a solution of nucleoside **73** (1.62 g, 0.003 mol) in ethanol (150 ml) was added 20% palladium hydroxide on carbon (3 g) and the suspension was stirred for 5 days under hydrogen. The catalyst was filtered off (silica gel) and washed with methanol (20 ml). The combined filtrate was concentrated under reduced pressure to give a white solid material which was filtered off and washed with methanol:dichloromethane (1:4, v/v) to give a monobenzylated intermediate (0.82 g, 76%). FAB-MS: m/e 360 $(M+H)^+$. ^{13}C-NMR (DMSO-d_6, 250 MHz): 163.7, 149.8 (C-2, C-4), 138.2 (Bn), 134.9 (C-6), 128.2, 127.5, 127.4 (Bn), 107.8 (C-5), 87.8, 87.6 (C-1', C-4'), 72.7, 68.9, 65.9, 61.7, 49.4 (C-2', C-3', C-5', C-1'', Bn), 11.9 (CH_3). Anal. Calcd. for $C_{18}H_{21}N_3O_5$: C, 60.16; H, 5.89; N, 11.69. Found: C, 59.86; H, 5.61; N, 11.56. A mixture of this intermediate (0.1 g, 0.29 mmol), ammonium formate (0.085g, 1.35 mmol), 10% palladium on carbon (130 mg) in anhydrous methanol (7 ml) was heated under reflux for 2 h. The catalyst was filtered off (silica gel) and washed with methanol (15 ml) and the combined filtrate was concentrated to dryness under reduced pressure. The residue was subjected to silica gel column chromatography using methanol:dichloromethane (1:9, v/v) as eluent to give title compound **74** (0.053 g, 71%) as a white solid material. FAB-MS *m/e* 270. δ_H (DMSO-d_6) 11.29 (bs, 1H, NH), 7.73 (d, 1H, *J* 1.1, 6-H), 5.31 (s, 1H, 1'-H), 5.29 (br s, 1H, 3'-OH), 5.13 (m, 1H, 5'-OH), 3.81 (s, 1H, 3'-H), 3.69 (m, 2H, 5'-H), 3.23 (s, 1H, 2'-H), 2.88 (d, 1H, *J* 9.8, 1''-H_a), 2.55 (d, 1H, *J* 9.8, 1''-H_b), 1.77 (d, 3H, *J* 0.8, CH_3). δ_C (DMSO-d_6) 164.0, 150.1 (C-2, C-4), 135.6 (C-6), 107.8 (C-5), 89.5, 87.9 (C-1', C-4'), 68.7, 61.9, 57.1, 49.4, (C-2', C-3', C-5', C-1''). Anal. Calcd. for $C_{11}H_{15}N_3O_5 \times 0.5\ H_2O$: C, 47.48; H, 5.80; N, 15.10. Found: C, 47.54; H, 5.30; N, 14.79.

Alternative method for conversion of 73 to 74. To a solution of **73** (0.045 g, 0.0834 mmol) in methanol (6 ml) was added 10% Pd on carbon (0.118 g) and - in three portions during 3 h - ammonium formate (0.145 g, 0.0023 mol). The suspension was refluxed for 4.5 h. The catalyst was filtered off (silica gel) and washed with methanol (4 x 3 ml). The combined filtrate was concentrated and the residue was subjected to column chromatography on silica gel using methanol:dichloromethane (1:9, v/v) as

130.9, 128.9, 128.9, 128.7, 128.7, 128.4, 127.7, 123.2, 114.1, 114.1, 114.0, 110.4, 89.4, 87.9, 87.5, 87.4, 87.2. 70.8, 69.0, 66.0, 64.4, 60.5, 60.2, 55.5, 53.6, 53.4, 49.9, 13.2, 13.1.

Example 89

1-(2-Amino-3-*O*-(2-cyanoethoxy(diisopropylamino)phosphino-2-deoxy)-5-*O*-4,4'-dimethoxytrityl-2-*N*,4-*C*-methylene-2-*N*-trifluoroacetyl-β-*D*-ribofuranosyl)thymine (74A). To a solution of nucleoside **74-DMT** (0.121 g, 0.181 mmol) in anhydrous dichloromethane (2 mL) were added *N,N*-diisopropylethylamine (0.093 mL, 0.54 mmol) and 2-cyanoethyl *N,N*-diisopropylphosphoramidochloridite (0.057 mL, 0.26 mmol) at 0 °C and the mixture was stirred for 10 h at room temperature. The mixture was diluted with dichloromethane (20 mL), extracted with a saturated aqueous solution of sodium hydrogencarbonate (3 x 10 mL), dried (Na_2SO_4) and filtered. The filtrate was evaporated to dryness under reduced pressure and the residue was subjected to column chromatography on silica gel using methanol:dichloromethane:-pyridine (1.5:98.0:0.5, v/v/v) as eluent to give crude product (0.107 g) after evaporation of the solvents under reduced pressure. The residue was dissolved in anhydrous dichloromethane (1 mL) and by dropwise addition to vigorously stirred petroleum ether (60-80 °C, 30 mL) at -30 °C, nucleotide **74A** precipitated to give a white solid material after filtration (0.090 g, 57%). FAB-MS *m/z* 868 $[M+H]^+$, 890 $[M+Na]^+$. ^{31}P NMR (CD_3CN, 121.5 MHz) δ 150.4, 150.2, 148.8, 149.1.

Example 90

1-(2-Amino-2-*N*,4-*C*-methylene-3,5-*O*-(tetraisopropyldisiloxane-1,3-diyl)-β-*D*-ribofuranosyl)thymine (74B). To a solution of nucleoside **74** (0.20 g, 0.74 mmol) in anhydrous pyridine (3 mL) at -15 °C was dropwise (during 3 h) added 1,3-dichloro-1,1,3,3-tetraisopropyldisiloxane (0.305 mL, 0.0011 mol) and the mixture was stirred for 10 h at room temperature. MeOH (3 mL) was added and the mixture was evaporated to dryness under reduced pressure. The residue was subjected to column chromatography on silica gel using methanol:dichloromethane (1:99, v/v) to give nucleoside **74B** as a white solid material after evaporation of the solvents under reduced pressure (0.370 mg, 97%). FAB-MS *m/z* 512 $[M+H]^+$. ^1H NMR ($(CD_3)_2SO$, 400 MHz) δ 11.37 (bs, 1H), 7.48 (s, 1H), 5.32 (s, 1H), 4.06 (d, 1H, *J* 13.5 Hz), 4.00 (s, 1H), 3.84 (d, 1H, *J* 13.5 Hz), 3.41 (s, 1H), 2.92 (d, 1H, *J* 10.2 Hz), 2.64 (d, 1H, *J*

combined filtrate was evaporated to dryness under reduced pressure to give an oily residue after coevaporation with methanol (2 x 5 mL). Column chromatography on silica gel using methanol:dichloromethane (1:49, v/v) as eluent gave nucleoside **74D** as a white solid material after evaporation of the solvents under reduced pressure (0.17 g, 79%). FAB-MS *m/z* 284 $[M+H]^+$. FAB-HRMS calcd. for $C_{12}H_{18}N_3O_5^+$: 284.12465. Found: 284.12402. ^1H NMR ($(CD_3)_2SO$, 400 MHz) δ 11.3 (bs, 1H, NH), 7.70 (d, 1H, *J* 1.1 Hz, 6-H), 5.50 (s, 1H, 1'-H), 5.26 (d, 1H, *J* 4.9 Hz, 3'-OH), 5.12 (t, 1H, *J* 5.7 Hz, 5'-OH), 3.87 (d, 1H, *J* 4.8 Hz, 3'-H), 3.67 (d, 2H, *J* 5.5 Hz, 5'-H), 3.12 (s, 1H, 2'-H), 2.87 (d, 1H, *J* 9.3 Hz, 5''-H_a), 2.56 (s, 3H, NCH_3), 2.52-2.49 (1H, m, 5''-H_b), 1.77 (s, 3H, CH_3). ^1H NMR (CD_3OD, 400 MHz) δ 7.80 (d, 1H, *J* 1.3 Hz, 6-H), 5.71 (s, 1H, 1'-H), 4.07 (s, 1H, 3'-H), 3.83 (s, 2H, 5'-H), 3.36 (s, 1H, 2'-H), 3.08 (d, 1H, *J* 9.9 Hz, 5''-H_a), 2.68 (s, 3H, NCH_3), 2.57 (d, 1H, *J* 9.9 Hz, 5''-H_b), 1.88 (d, 3H, *J* 1.1 Hz, CH_3). ^{13}C NMR (CD_3OD, 62.9 MHz) δ 166.6, 151.9, 137.4, 110.4, 91.3, 85.2, 71.4, 69.1, 59.4, 58.7, 40.2, 12.2.

Example 93

1-(2-Deoxy-5-*O*-4,4'-dimethoxytrityl-2-methylamino-2-*N*,4-*C*-methylene-β-*D*-ribofuranosyl)thymine (74E). To a solution of nucleoside **74D** (0.135 g, 0.477 mmol) in anhydrous pyridine (1.5 mL) at 0 °C was dropwise (during 20 min) added a solution of 4,4'-dimethoxytrityl chloride (0.238 g, 0.702 mmol) in anhydrous pyridine:dichloromethane (1.0 mL, 1:1, v/v) and the resulting mixture was stirred for 10 h at RT. A mixture of ice and water was added (5 mL) and the mixture was extracted with dichloromethane (3 x 10 mL). The combined organic phase was washed with a saturated aqueous solution of sodium hydrogencarbonate (3 x 5 mL), dried (Na_2SO_4) and filtered. The filtrate was evaporated to dryness under reduced pressure and the residue was subjected to column chromatography on silica gel using methanol:-dichloromethane:pyridine (1:98:1, v/v/v) as eluent to give nucleoside **74E** as a white solid material after evaporation of the solvents under reduced pressure (0.20 g, 72%). FAB-MS *m/z* 586 $[M+H]^+$. ^1H NMR (C_5D_5N, 400 MHz) δ 13.2 (bs, 1H), 7.98 (d, 1H, *J* 1.3 Hz), 7.98-7.00 (m, 13H), 6.12 (s, 1H), 4.78 (d, 1H, *J* 3.7 Hz), 3.88-3.79 (m, 4H), 3.71 (s, 3H), 3.71 (s, 3H), 3.29 (d, 1H, *J* 9.3 Hz), 2.84 (d, 1H, *J* 9.3 Hz), 2.81 (s, 3H), 1.85 (d, 3H, *J* 0.9 Hz). ^{13}C NMR (C_5D_5N, 62.9 MHz) δ 165.1, 159.2, 151.4, 145.9, 136.5, 136.4, 130.8, 130.7, 128.7, 128.4, 127.4, 113.8, 109.6, 89.8,

CH_3), 2.34 (3H, s, CH_3). δ_C ($CDCl_3$) 162.2 (C-4), 149.5 (C-2), 146.0, 145.3 (Ts), 139.0 (C-6), 136.7, 131.9, 130.0, 129.9, 128.9, 128.7, 128.5, 128.4, 128.3, 128.2, 128.0, 127.6 (Bn, Ts) 102.7 (C-5), 85.5 (1'-C), 84.4 (4'-C), 79.2, 78.3, 75.1, 74.3, 72.4, 69.1 (Bn, 3'-C, 2'-C, 5'-C, 1''-C), 21.7, 21.6 (Ts). FAB-MS *m/z* 763. Found: C, 61.2 ;H, 4.4; N, 3.3; $C_{38}H_{38}N_2O_{11}S_2$ requires C, 59.8; H,5.0; N,3.6.

Example 96

1-(2-Deoxy-3,5-di-*O*-benzyl-2-*S*,4-*C*-methylene-2-mercapto-β-*D*-ribofuranosyl)thymine (76). To a stirred solution of nucleoside **75** (3.70g, 4.86 mmol) in DMF (40 cm^3) was added potassium thioacetate (0.83 g, 7.28 mmol). The mixture was stirred and heated at 110 °C for 80 h. After evaporation under reduced pressure, H_2O (100 cm^3) was added. Extraction was performed with dichloromethane (4 x 50 cm^3) and the combined organic phase was dried (Na_2SO_4), filtered and evaporated under reduced pressure. The residue was purified by silica gel chromatography using dichloromethane/methanol (99.6:0.4, v/v) as eluent to give nucleoside **76** (1.65g, 75%) as a white solid material. δ_H ($CDCl_3$) 9.08 (1H, br s, NH), 7.98 (1H, d, *J* 8.1, 6-H), 7.39-7.20 (10H, m, Bn), 5.85 (1H, s, 1'-H), 5.26 (1H, d, *J* 8.1, 5-H), 4.61 (1H, d *J* 11.4, 5'-H), 4.56 (2H, s, Bn), 4.45 (1H, d, *J* 11.4, Bn), 4.14 (1H, d, *J* 1.7, 3'-H), 3.82 (2H, m, Bn), 3.72 (1H, d, *J* 1.9, 2'-H), 3.02 (1H, d, *J* 9.9, 1''-H_a), 2.78 (1H, d, *J* 9.9, 1''-H_b). δ_C ($CDCl_3$) 163.4 (C-4), 150.0 (C-2), 139.9 (C-6), 137.2, 136.8, 128.6, 128.5, 128.2, 127.9, 127.7 (Bn), 100.8 (C-5), 90.8, 88.8 (C-1', C-4'), 76.5, 73.8, 72.0, 70.0 (2 x Bn, C-3', C-5'), 49.52 (C-2'), 35.63 (C-1''). FAB-MS *m/z* 453. Found: C, 63.4; H, 5.1;N, 5.9; $C_{24}H_{24}N_2O_6S$ requires C, 63.7; H, 5.3; N, 6.1.

Example 97

1-(2-*O*-*p*-Toluenesulfonyl-4-*C*-(*p*-toluenesulfonyloxymethyl)-β-*D*-ribofuranosyl)uracil (76A). To a solution of compound **75** (0.80 g, 1.0 mmol) in absolute ethanol (2 cm^3) was added 20% palladium hydroxide over carbon (0.80 g) and the mixture was degassed several times with hydrogen and stirring was continued under hydrogen for 48 h. The catalyst was filtered off and the filtrate was evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dichloromethane/methanol (99:1, v/v) as eluent to give nucleoside **76A** (0.30 g, 49%) as a white solid material. δ_H (CD_3OD) 7.67 (4H, m), 7.45 (1H, d, *J* 8.2 Hz), 7.34 (4H, m), 5.86 (1H, d, *J* 8.0 Hz), 5.40 (1H, d, *J* 8.1 Hz), 4.95 (1H, m), 4.35 (1H, d, *J* 5.0

163.2, 149.8, 139.6, 100.9, 91.4, 90.7, 71.5, 59.8, 51.5, 34.4, 17.5, 17.3, 17.1, 16.9, 15.5, 13.6, 13.3, 13.1, 12.9, 12.3. FAB-MS *m/z* 515 $[M+H]^+$.

Example 100

1-(2-Deoxy-2-mercapto-2-*S*,4-*C*-methylene-β-*D*-ribofuranosyl)uracil (76D). To a stirred solution of nucleoside **76C** (25 mg, 0.049 mmol) in THF (1.0 cm^3) was added a solution of tetrabutylammonium flouride (0.20 cm^3 of a 1M solution in THF, 0.20 mmol) at 0°C. After stirring the mixture at 0°C for 1 h, H_2O (5 cm^3) was added and the mixture was evaporated. The residue was purified by silica gel column chromatography using dichloromethane/methanol (97:3, v/v) as eluent to give nucleoside **76D** (9.0 mg, 69%) as a white solid material. δ_H (CD_3OD) 8.19 (1H, d, *J* 8.1 Hz, 6-H), 5.77 (1H, s, 1'-H), 5.65 (1H, d, *J* 8.1 Hz, 5-H), 4.31 (1H, d, *J* 2.1 Hz, 3'-H), 3.86 (2H, s, 5'-H), 3.53 (1H, d, *J* 2.2 Hz, 2'-H), 2.93 (1H, d, *J* 10.3 Hz, 1''-H_a), 2.73 (1H, d, *J* 10.3 Hz, 1''-H_b). δ_C (CD_3OD) 166.5, 152.0, 141.7, 101.2, 92.1, 92.0, 71.4, 59.9, 53.6, 35.4. FAB-MS *m/z* 273 $[M+H]^+$.

Example 101

1-(2-Deoxy-5-*O*-(4,4'-dimethoxytrityl)-2-mercapto-2-*S*,4-*C*-methylene-β-*D*-ribofuranosyl)uracil (76E). To a solution of **76D** (0.2 g, 0.37 mmol) in anhydrous pyridine (5 cm^3) was added 4,4'-dimethoxytrityl chloride (0.186 g, 0.55 mmol) at room temperature. The solution was stirred for 5 h whereupon the reaction mixture was cooled to 0 °C. A saturated aqueous solution of sodium hydrogen carbonate (30 cm^3) was added and the resulting mixture was extracted with dichloromethane (3 x 50 cm^3). The combined organic phase was separated and dried (Na_2SO_4). The solvent was removed under reduced pressure and the residue was purified by silica gel column chromatography with dichloromethane/methanol/pyridine (98.5:1.0:0.5 v/v) as eluent to give nucleoside **76E** as a white brownish solid material (0.175 g, 83%). δ_C ($CDCl_3$) 164.5, 159.4, 151.6, 145.7, 139.9, 136.4, 136.0, 135.6, 130.9, 130.8, 128.8, 128.5, 128.4, 127.5, 127.4, 122.7, 113.9, 101.5, 91.7, 90.2, 87.6, 71.8, 61.9, 55.3, 53.7, 36.2, 30.6. FAB-MS *m/z* 574 $[M]^+$, 575 $[M+H]^+$ (Found: C, 65.2; H, 5.4; N, 5.0; $C_{31}H_{30}N_2O_7S$ requires C, 64.8; H, 5.3; N, 4.9%).

84.7 (C-4), 79.0, 78.7, 73.7, 72.7, 70.7, 70.2, (Bn, C-2, C-3, C-5, C-1'), 26.3, 26.0 ($C(CH_3)_2$), 21.6 (CH_3). FAB-MS *m/z* 555 $[M+H]^+$. (Found: C, 64.8; H, 6.2; $C_{30}H_{34}O_8S$ requires C, 64.9; H, 6.1%).

Example 104

1,2-Di-*O*-acetyl-3,5-di-*O*-benzyl-4-*C*-(*p*-toluenesulfonyloxymethyl)-α,β-D-ribofuranose (78). A solution of furanose **77** (17.4 g, 31.4 mmol) in 80% acetic acid (250 cm^3) was stirred at 60 °C for 20 h. The solvent was removed *in vacuo* and the residue was coevaporated with toluene (3 x 20 cm^3). The residue was redissolved in anhydrous pyridine (100 cm^3). Acetic anhydride (14.2 cm^3) was added and the solution was stirred for 15 h at room temperature. The reaction was quenched by addition of ice-cold H_2O (200 cm^3), and the mixture was extracted with dichloromethane (4 x 150 cm^3). The combined organic phase was washed with saturated aqueous solutions of sodium hydrogen carbonate (2 x 125 cm^3) and brine (3 x 150 cm^3), dried (Na_2SO_4), filtered and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dicloromethane:methanol (98.5:1.5, v/v) as eluent to give **78** (α,β~1:1) as a clear oil (13.5 g, 72%). δ_C ($CDCl_3$) 169.8, 169.6, 69.4, 168.8 (C=O), 144.7, 137.7, 137.5, 132.8, 129.7, 129.6, 128.5, 128.4, 128.3, 128.2, 128.0, 127.8, 127.7, 127.6 (Bn), 97.4, 94.2 (C-1), 86.4, 84.2 (C-4), 78.9, 77.5, 74.5, 74.1, 73.7, 73.5, 71.8, 70.6, 70.5, 69.6, 69.5 (Bn, C-2, C-3, C-1'), 21.6, 21.0, 20.8, 20.6, 20.4 ($COCH_3$, $C(CH_3)_2$). FAB-MS *m/z* 599 $[M+H]^+$.

Alternative procedure for the preparation of compound 78.

3-O-Benzyl-1,2:5,6-di-O-isopropylidene-α-D-glucofuranose (30B). To a solution of 1,2:5,6-Di-O-isopropylidene-α-D-allofuranose (**30A**) (obtained from Pfanstiehl Laboratories Inc.) (40 g) in dimethylformamide at 0 °C was added sodium hydride in smaller portions. The reaction mixture was stirred for 1 h, benzyl bromide was added drop wise over a period of 1 h. The reaction mixture was stirred at room temperature for 16 h. Methanol was added to quench the reaction and dimethylformamide was removed under pressure. The syrup was extracted with ethyl acetate and washed with brine. Evaporation of the ethyl acetate layer yielded a semisolid (93%). Homogeneous by TLC.

1,2-di-O-acetyl-3,5-di-O-benzyl-4-C-tosyl-D-ribofuranose (78). Hydrolysis of **77** (14 g) was done in 75% acetic acid at 65 °C for 18 h. The solvent was removed under pressure and the residue was treated with ethanol (3x100), toluene (3x50) and anhydrous pyridine (2x50). (This compound **78** crystallised from petroleum ether as fine white solid.) The residue was taken in dry pyridine and treated with acetic anhydride at room temperature for 8 h. Extraction with ethyl acetate and saturated bicarbonate followed by washing with brine afforded **78** as a mixture of α and β anomers, 12g, (83%). A direct comparison with an authentic sample of **78** (TLC, HPLC, NMR) confirmed its identity and purity.

Example 105

1-(2-*O*-Acetyl-3,5-di-*O*-benzyl-4-*C*-(*p*-toulenesulfonyloxymethyl)-β-D-ribofuranosyl)-thymine (79). To a stirred solution of the anomeric mixture **78** (12.8 g, 21.4 mmol) and thymine (5.38 g, 42.7 mmol) in anhydrous acetonitrile (182 cm^3) was added *N,O*-bis(trimethylsilyl)acetamide (31.68 ml, 128.23 mmol). The reaction mixture was stirred for 1 h at room temperature, and stirring was continued at 60 °C for 1.5 h. After cooling to 0 °C, trimethylsilyl triflate (6.57 ml, 30.33 mmol) was added dropwise, and the mixture was stirred at 60 °C for 10 h. The reaction mixture was neutralised with an ice-cold saturated aqueous solution of sodium hydrogen carbonate (90 mL). The reaction mixture was filtered, and the filtrate was concentrated under reduced pressure to half volume. Extraction was performed using dichloromethane (4 x 200 cm^3). The combined organic phase was washed with saturated aqueous solutions of sodium hydrogen carbonate (3 x 150 cm^3) and brine (3 x 150 ml), dried (Na_2SO_4), filtered and evaporated under reduced pressure. The residue was purified by silica gel column chromatography using dicloromethane:methanol (99:1 to 98:2, v/v) as eluent to give nucleoside **79** as a white solid material (13.1 g, 92%). δ_H ($CDCl_3$) 9.04 (s, 1H, NH), 7.73-7.19 (15H, m, 6-H, aromatic), 5.94 (1H, d, *J* 5.5, 1'-H), 5.37 (1H, d, *J* 5.6, 2'-H), 4.57-4.40 (5H, m, 3'-H, 5'-H_a, 5'-H_b, Bn), 4.14 (2H, s, Bn), 3.75 (1H, d, *J* 10.2, 1''-H_a), 3.57 (1H, d, *J* 10.2, 1''-H_b), 2.41 (3H, s, $CH_3C_6H_5$), 2.02 (3H, s, $COCH_3$), 1.54 (3H, s, CH_3). δ_C ($CDCl_3$) 169.8 (C=O), 163.5 (C-4), 150.2 (C-2), 145.0, 136.8, 135.6, 132.1, 129.7, 128.5, 128.0, 127.9, 127.8, 127.5 (aromatic), 113.5 (C-5), 86.8, 85.3, 77.6, 74.6, 74.3, 73.6, 70.8, 68.8 (Bn, C-1', C-3', C-2', C-4'), 21.3 (CH_3), 20.5 ($COCH_3$), 11.8 (CH_3). FAB-MS *m/z* 665 $[M+H]^+$ (Found C, 61.2; H, 5.3; N, 4.1; S, 4.7, $C_{34}H_{36}O_{10}N_2S$ requires C, 61.4; H, 5.4; N, 4.2; S, 4.8).

solid material (7.1 g, 92%). Spectral data were in accordance with data given earlier for **36** (Found C, 66.2; H, 5.8; N, 6.1; $C_{25}H_{26}N_2O_8$ requires C, 66.6; H, 5.8; N, 6.2).

Example 108

3,5-Di-*O*-benzyl-1,2-*O*-isopropylidene-4-*C*-methanesulfonyloxymethyl-α-D-ribofuranose (200). To a stirred solution of furanose **31** (2.16 g, 5.39 mmol) in anhydrous pyridine (3 mL) at 0°C was added dropwise methanesulfonyl chloride (0.61 mL, 16.0 mmol). The reaction mixture was stirred for 20 min at room temperature, quenched with ice-cold water (300 mL) and extracted with dichloromethane (2x300 mL). The combined extracts were washed with saturated aqueous sodium hydrogen carbonate (300 mL) and then dried ($MgSO_4$). The solvent was removed by distillation under reduced pressure and the residue was purified by chromatography over silica gel with dichloromethane as eluent to give the product **200** as a clear oil (2.55 g, 99%); ^{1}H NMR ($CDCl_3$): δ 7.37-7.24 (10 H, m, Bn), 5.78 (1 H, d, *J* 3.8 Hz, H-1), 4.85 (1 H, d, *J* 11.7 Hz, Bn), 4.73 (1 H, d, *J* 11.9 Hz, Bn), 4.64 (1 H, dd, *J* 4.0, 5.3 Hz, H-2), 4.54 (1 H, d, *J* 11.9 Hz, H-5'), 4.52 (1 H, d, *J* 11.9 Hz, Bn), 4.46 (1 H, d, *J* 11.9 Hz, H-5'), 4.41 (1 H, d, *J* 11.8 Hz, Bn), 3.60 (1 H, d, *J* 10.4 Hz, H-5), 3.50 (1 H, d, *J* 10.5 Hz, H-5), 3.06 (3 H, s, SO_2CH_3), 1.68 (3 H, s, CH_3), 1.34 (3 H, s, CH_3); ^{13}C NMR ($CDCl_3$): δ 137.79, 137.31, 128.54, 128.48, 128.16, 128.01, 127.87, 127.79 (Bn), 113.66 ($C(CH_3)_2$), 104.46 (C-1), 84.88 (C-4), 78.48, 78.41 (C-2, C-3), 73.65, 72.63, 70.78, 70.16 (Bn, C-5, C-5'), 37.84 (SO_2CH_3), 26.20 (CH_3), 25.69 (CH_3); MS FAB: 501 (M+Na, 100%). Found: C, 60.37; H, 6.29; S, 6.53; $C_{24}H_{30}O_8S$ requires C, 60.24; H, 6.32; S, 6.70 %.

Example 109

Methyl 3,5-di-*O*-benzyl-4-*C*-methanesulfonyloxymethyl-α-D-ribofuranoside (201). A solution of furanose **200** (1.133 g, 2.37 mmol) in methanolic hydrochloric acid (20% w/w, 31.7 mL) and water (4.4 mL) was stirred at room temperature for 2 h. After neutralisation with sodium hydrogen carbonate (s), the solution was extracted with dichloromethane (2x150 mL). The combined extracts were washed with water (150 mL) and then dried ($MgSO_4$). The solvent was removed by distillation under reduced pressure and the residue purified by chromatography over silica gel with dichloro-methane:methanol (99:1) as eluent to give the product **201** (β:α ~ 2:1) as a clear oil (1.018 g, 95%); ^{1}H NMR ($CDCl_3$): δ 7.39-7.22 (m, Bn), 4.86 (br s, Bn), 4.69-3.99 (m,

88.44 (C-4), 79.54 (C-3), 77.16 (C-2), 73.68 (Bn), 72.61 (C-5'), 72.24 (Bn), 65.73 (C-5), 56.20 (OCH_3); MS FAB: 379 (M+Na, 100%).

Example 111

(*1R,2S,3S*)-2-Benzyloxy-3-benzyloxymethyl-1-(methoxy(thymin-1-yl)methyl)-3-trimethylsilyloxytetrahydrofuran (204). A solution of **202** (216 mg, 0.606 mmol) and thymine (153 mg, 1.22 mmol) in anhydrous acetonitrile (9.3 mL) was added BSA (*N,O*-bis(trimethylsilyl)acetamide, 0.90 mL, 3.6 mmol) and stirred under reflux for 15 min. The solution was cooled to 0°C and trimethylsilyl triflate (0.153 mL, 0.777 mmol) was added dropwise. After stirring at room temperature for 18 h and at 60°C for 24 h, the reaction was quenched with a saturated aqueous solution of sodium hydrogen carbonate (20 mL), and extraction was performed using dichloromethane (2x50 mL). The combined extract was washed with a saturated aqueous solution of sodium hydrogen carbonate (50 mL) and dried ($MgSO_4$). The solvent was removed under reduced pressure and the residue was purified by chromatography over silica gel with dichloromethane:methanol (98:2) as eluent to give the product **204** (mixture of diastereomers ~ 1.7:1) as a solid (196 mg, 67%). ^{1}H NMR ($CDCl_3$): δ 7.36-7.14 (m, Bn, H-6), 5.77 (1 H, d, *J* 7.9 Hz, H-1'), 5.57 (1 H, d, *J* 5.8 Hz, H-1'), 4.68-4.43 (m, Bn, H-2'), 4.12-3.68 (m, H-5', H-5', H-3'), 3.32 (s, OCH_3), 3.24 (s, OCH_3), 1.93 (d, *J* 0.9 Hz, CH_3), 1.86 (d, *J* 1.1 Hz, CH_3), 0.14 (s, $Si(CH_3)_3$), 0.12 (s, $Si(CH_3)_3$); ^{13}C NMR ($CDCl_3$): δ 163.68, 163.55 (C-4), 151.58, 151.07 (C-2), 137.84, 137.74, 137.32 (Bn), 135.93, 135.10 (C-6), 128.57, 128.42, 128.41, 128.10, 127.95, 127.85, 127.77, 127.74 (Bn), 111.38, 111.01 (C-5), 86.89, 85.61, 85.40, 84.72, 83.40, 83.31, 82.10 (C-1', C-2', C-3', C-4'), 75.20, 73.98, 73.62, 73.59, 72.55, 72.13, 71.04, 70.74 (Bn, C-5', C-5''), 56.82, 56.54 (OCH_3), 12.47, 12.38 (CH_3), 1.72, 1.69 ($Si(CH_3)_3$); MS FAB: 555 (M+H, 65%), 577 (M+Na, 70%). Found: C, 62.76; H, 6.88; N, 4.94; $C_{29}H_{38}N_2O_7Si$ requires C, 62.79; H, 6.90; N, 5.05 %.

Example 112

(*1R,2S,3S*)-2-Benzyloxy-3-benzyloxymethyl-1-(methoxy(6-*N*-benzoyladenin-9-yl)-methyl)-3-trimethylsilyloxytetrahydrofuran (205). A solution of **202** (240 mg, 0.673 mmol) and 6-*N*-benzoyladenine (301 mg, 1.26 mmol) in anhydrous acetonitrile (8.2 mL) was added BSA (0.67 mL, 2.7 mmol) and stirred at room temperature for 1 h. The solution was cooled to 0°C and trimethylsilyl triflate (0.25 mL, 1.33 mmol) was

pyridine (2.0 mL) was added acetic anhydride (0.18 mL, 1.91 mmol). The reaction mixture was stirred for 23 h at room temperature, water (0.13 mL) was added, and the solvent was removed by distillation under reduced pressure. The residue was coevaporated in toluene (3x10 mL) and purified by chromatography over silica gel with dichloromethane:methanol (99:1) as eluent to give the product **207** as an clear oil (56.7 mg, 23%); ^{1}H NMR ($CDCl_3$): δ 7.38-7.26 (10 H, m, Bn), 6.00 (1 H, s, H-1), 4.68 (1 H, d, *J* 12.0 Hz, Bn), 4.62 (1 H, d, *J* 12.2 Hz, Bn), 4.60 (1 H, d, *J* 12.4 Hz, Bn), 4.56 (1 H, d, *J* 12.2 Hz, Bn), 4.17 (1 H, s, H-2), 4.14 (1 H, s, H-3), 4.01 (1 H, d, *J* 7.7 Hz, H-5'), 3.81-3.78 (3 H, m, H-5', H-5), 20.06 (3 H, s, $COCH_3$); ^{13}C NMR ($CDCl_3$): δ 169.18 (C=O), 137.92, 137.48, 128.52, 128.45, 128.03, 127.77, 127.73, 127.68 (Bn), 95.95 (C-1), 86.49 (C-4), 78.27, 76.58 (C-3, C-2), 73.65 (Bn), 72.26, 71.96 (Bn, C-5'), 65.49 (C-5), 20.98 ($COCH_3$); MS FAB: 407 (M+Na, 55%). Found: C, 68.80; H, 6.11; $C_{22}H_{24}O_6$ requires C, 68.74; H, 6.29 %.

Example 115

***(1S,3S,4R,7S)*-3-(6-*N*-Benzoyladenin-9-yl)-7-benzyloxy-1-benzyloxymethyl-2,5-dioxabicyclo[2.2.1]heptane (208).** A solution of furanose **207** (167 mg, 0.434 mmol) and 6-*N*-benzoyladenine (194 mg, 0.813 mmol) in anhydrous acetonitrile (5.3 mL) was added BSA (0.43 mL, 1.76 mmol) and stirred at room temperature for 1 h. The solution was cooled to 0 °C and trimethylsilyl triflate (0.16 mL, 0.86 mmol) was added dropwise. After stirring at 65 °C for 2 h, the reaction was quenched with a saturated aqueous solution of sodium hydrogen carbonate (40 mL) and the mixture was extracted with dichloromethane (2x50 mL). The combined extract was dried ($MgSO_4$). The solvent was removed under reduced pressure and the residue was purified by chromatography over silica gel with dichloromethane:methanol (98:2) as eluent to give the product **208** as a solid (111 mg, 45%); ^{1}H NMR ($CDCl_3$): δ 8.82 (1 H, s, H-8), 8.14 (1 H, s, H-2), 7.59-7.26 (15 H, m, Bz, Bn), 6.74(1 H, s, H-1'), 4.92 (1 H, s, H-2'), 4.74-4.39 (4 H, m, Bn), 4.42 (1 H, s, H-3'), 4.19-4.10 (2 H, m, H-5''), 3.92 (1 H, d, *J* 11.8 Hz, H-5'), 3.88 (1 H, d, *J* 11.5 Hz, H-5'); MS FAB: 564 (M+H, 100%).

Example 116

Methyl 2-*O*-acetyl-3,5-di-*O*-benzyl-4-*C*-methanesulfonyloxymethyl-D-ribofuranoside (209). To a stirred solution of **201** (687 mg, 1.52 mmol) in anhydrous pyridine (4 mL)

the product **210** as a clear oil (564 mg, 66%) and unreacted starting material (191 mg, 26%); *Method b.* A stirred solution of **211** (86 mg, 0.165 mmol) in anhydrous dichloromethane (0.49 mL) was added phenylthiotrimethylsilane (0.16 mL, 0.825 mmol) and cooled to 0°C. Trimethylsilyl triflate (0.037 mL, 0.206 mmol) was added and the solution was stirred at room temperature for 2 h. The reaction was quenched with a saturated aqueous solution of sodium hydrogen carbonate (15 mL) and the resulting mixture was extracted with dichloromethane (2x25 mL). The combined extract was dried ($MgSO_4$) and the solvent removed by distillation under reduced pressure. The residue was purified by chromatography over silica gel with dichloromethane as eluent to give the product **210** as a clear oil (75 mg, 79%); ^1H NMR ($CDCl_3$): δ 7.47-7.19 (15 H, m, Bn, SPh), 5.48 (1 H, d, *J* 3.6 Hz, H-2), 5.34 (1 H, dd, *J* 3.7, 5.2 Hz, H-1), 4.54-4.36 (7 H, m, H-3, H-5', Bn), 3.66 (1 H, d, *J* 9.7 Hz, H-5), 3.48 (1 H, d, *J* 9.5 Hz, H-5), 2.89 (3 H, s, SO_2CH_3), 2.09 (3 H, s, $OCCH_3$); ^{13}C NMR ($CDCl_3$): δ 169.93 (C=O), 137.69, 137.08, 132.65, 132.45, 129.15, 128.53, 128.52, 128.18, 128.14, 128.08, 127.91, 127.85 (Bn, SPh), 87.99, 84.35, 80.34, 75.33, 74.20, 73.67, 70.83, 69.34 (C-1, C-2, C-3, C-4, C-5, C-5', Bn), 37.27 (SO_2CH_3), 20.68 ($OCCH_3$); MS FAB: 463 (M-SPh, 100%), 595 (M+Na, 24%); Found: C, 61.17; H, 5.55; $C_{29}H_{32}O_8S_2$ requires C, 60.82; H, 5.63 %.

Example 118

1,2-Di-*O*-acetyl-3,5-di-*O*-benzyl-4-*C*-methanesulphonyloxymethyl-D-ribofuranose (211). A solution of **201** (150 mg; 0.313 mmol) in 80% aqueous acetic acid (1.5 mL) was stirred at 90°C for 3 h. The solvent was removed by distillation under reduced pressure and the residue was coevaporated in ethanol (3x5 mL), toluene (3x5 mL) and pyridine (2x5 mL). The residue was redissolved in anhydrous pyridine (0.62 mL) and added acetic anhydride (0.47 mL) and the solution was stirred at room temperature for 16 h. The reaction was quenched with water (50 mL) and the resulting mixture extracted with dichloromethane (2x50 mL). The combined extract was washed with an aqueous saturated solution of sodium hydrogen carbonate (50 mL) and dried ($MgSO_4$). The solvent was evaporated and the residue purified on column chromatography over silica gel with dichloromethane as eluent to give the product **211** as an oil (99 mg, 60%); ^1H NMR ($CDCl_3$): δ 7.39-7.21 (m, Bn), 6.38 (d, *J* 4.6 Hz, H-1 β), 6.15 (s, H-1 α), 5.35 (d, *J* 4.9 Hz, H-2 α), 5.17 (dd, *J* 6.3, 4.9 Hz, H-2 β), 4.69-4.23 (m, H-3, Bn), 3.64 (d, *J* 9.7 Hz, H-5 α), 3.52 (d, *J* 10.1 Hz, H-2 β), 3.45

137.46, 135.29, 130.93, 129.13, 128.99, 128.57, 128.48, 127.81, 127.76, 127.58, 126.95 (Bn, SPh), 91.87 (C-1), 88.59 (C-4), 80.07, 79.14 (C-2, C-3), 73.65, 73.40, 72.04 (Bn, C-5'), 65.62 (C-5).

Example 120

(*3R*)- and (*3S*)-(*1S,4R,7S*)-7-Benzyloxy-1-benzyloxymethyl-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane (36+213). Thymine (175 mg, 1.38 mmol) was stirred in hexamethyldisilazane (6.8 mL) at reflux and ammonium sulphate (5 mg) was added. After stirring for 16 h, the clear solution was cooled to 40°C and the solvent was removed by distillation under reduced pressure. To the residue was added a solution of **212** (201 mg, 0.463 mmol) in anhydrous dichloromethane (4.6 mL) and 4Å molecular sieves (180 mg). After stirring at room temperature for 10 min, NBS (107 mg, 0.602 mmol) was added and the mixture stirred for another 30 min. The reaction was quenched with a saturated aqueous solution of sodium thiosulphate (25 mL) and the resulting mixture was extracted with dichloromethane (2x50 mL). The combined extract was dried ($MgSO_4$) and evaporated, and the residue was purified on column chromatography over silica gel with dichloromethane:methanol (97:3) as eluent to give the product **36+213** and as an anomeric mixture (β:α~1:2) (127 mg, 61%); ^{1}H NMR ($CDCl_3$): δ 7.49 (d, *J* 0.9 Hz, H-6 β), 7.46 (d, *J* 1.0 Hz, H-6 α), 7.39-7.25 (m, Bn), 5.94 (s, H-1' α), 5.64 (s, H-1' β), 4.71-4.50 (m, Bn, H-2'), 4.23 (s, H-3' α), 4.16 (d, *J* 8.6 Hz, H-5"α), 4.09-3.78 (m, H-5', H-5", H-3'β), 1.94 (d, *J* 0.9 Hz, CH_3 α), 1.62 (d, *J* 1.2 Hz, CH_3 β); MS FAB: 551 (M+H, 96%).

Example 121

(*3R*)- and (*3S*)-(*1S,4R,7S*)-7-Hydroxy-1-hydroxymethyl-3-(thymin-1-yl)-2,5-dioxabicyclo[2.2.1]heptane (37+214). A solution of **36+213** (175 mg, 0.39 mmol) in ethanol (2.7 mL) was stirred at room temperature and 20% palladium hydroxide over carbon (50 mg) was added. The mixture was degassed several times with argon and placed under a hydrogen atmosphere. After stirring for 18 h, the mixture was purified on column chromatography over silica gel with dichloromethane:methanol (95:5) as eluent to give a mixture of **37** and **214** (1:1.2) (26 mg, 25%); ^{1}H NMR (CD_3OD): δ 7.78 (d, *J* 1.3 Hz, H-6 α), 7.73 (d, *J* 1.2 Hz, H-6 β), 5.88 (s, H-1' α), 5.53 (s, H-1' β), 4.38 (s, H-2' α), 4.34 (s, H-3' α), 4.26 (s, H-2' β), 4.08-3.69 (m, H-5', H-5", H-3'β), 1.92 (d, *J* 1.2 Hz, CH_3 α), 1.88 (d, *J* 1.1 Hz, CH_3 β); ^{13}C NMR (CD_3OD): δ 138.00 (C-

General method for phosphitylation of protected LNA nucleosides. Base protected dimethoxytrityl-LNA nucleoside was coevaporated with anhydrous dichloromethane (2x) and was taken in anhydrous dichloromethane (10 ml/g of nucleoside for A,G &T and ~30 ml/g for C). To this bis(diisopropylamino)(2-cyanoethyl)phosphite (1.05-1.10 equivalent), followed by tetrazole (0.95 equivalent) were added. Mixture was stirred at room temperature and reaction was followed by HPLC (70% acetonitrile in 0.1M TEAA, pH 7, 2 min., 70-100% acetonitrile in 8 min., and 100% acetonitrile in 5 min., flow rate: 1 ml/min., Novapak C-18 column). Once the reaction had proceeded to >90% and no more increase in amidite formation was observed upon further stirring, the mixture was cooled in ice. It was diluted with dichloromethane (~15-20 times the original volume) and washed with cold saturated sodium bicarbonate (2x) followed by cold brine (1x). Organic layer was dried over anhydrous sodium sulfate, filtered and concentrated on rotavap. Residue was coevaporated with anhydrous acetonitrile (3x) and dried *in vacuo* overnight. HPLC purity ranged from 93-98%.

Preparation of LNA nucleoside 5'-triphosphates

Example 123

Synthesis of LNA nucleoside 5'-triphosphates. (*Tetrahedron Letters* **1988**, *29* 4525). In a 13x100 mm polypropylene tube, nucleosides **37**, **44**, **51**, 4-N-benzoylated **57A** or **61B** (93.8 µmol) was suspended in 1 mL pyridine (dried by CaH_2). The solution was evaporated in a speedvac, under high vacuum, to dryness. The residue was twice resuspended in acetonitrile (dried by CaH_2) and evaporated to dryness. The nucleoside was suspended in 313 µL trimethyl phosphate (dried by 4Å molecular sieves), to which 30.1 mg Proton Sponge™ (1.5 equivalents) were added. The mixture was sealed, vortexed, and cooled to 0° C. $POCl_3$ (9.8 µL, 1.1 equivalent) was added with vortexing. The reaction was allowed to proceed at 0°C for 2.5 hours. During this interval, 469 µmols sodium pyrophosphate (5 equivalents) were dissolved in 5 mL water and passed through 5 mL Dow 50 H^+ ion exchange resin. When the effluent turned acidic, it was collected in 220µL tributylamine and evaporated to a syrup. The TBA pyrophosphate was coevaporated three times with dry acetonitrile. Finally, the dried pyrophosphate was dissolved in 1.3 mL DMF (4Å sieves). After 2.5 hours reaction time, the TBA pyrophosphate and 130 µL tributylamine were added to the nucleoside solution with vigorous vortexing. After 1 minute, the reaction was

Example 125

Synthesis of phosphorothioate LNA oligonucleotides. The all-phosphorothioate LNA (Table 7) was synthesised on an automated DNA synthesiser using similar conditions as those described earlier (Example 124). Beaucages' reagent was used as sulphurising agent. The stepwise coupling yields were >98%. After completion of the syntheses, deprotection and cleavage from the solid support was effected using concentrated ammonia (55 °C, 14 h).

Example 126

Synthesis of 2'-Thio-LNA oligonucleotides. The 2'-thio-LNA oligonucleotides (containing monomer $\mathbf{U^S}$ (formula Z (thio-variant) of Figure 2), Figure 37, Table 8) were synthesised on an automated DNA synthesiser using standard conditions (Example 124). The step-wise coupling yield for amidite **76F** was approximately 85% (12 min couplings; improved purity of amidite **76F** is expected to result in increased coupling yield). After completion of the syntheses, deprotection and cleavage from the solid support was effected using concentrated ammonia (55 °C, 8 h).

Example 127

Synthesis of 2'-Amino-LNA oligonucleotides. By procedures similar to those described in Example 126, 2'-Amino-LNA oligonucleotides (containing monomer $\mathbf{T^{NH}}$ and monomer $\mathbf{T^{NMe}}$ (formula Z (amino variants) of Figure 2), Figures 35 and 36) was efficiently obtained on an automated DNA synthesiser using amidites **74A** and **74F** (≥98% stepwise coupling yields).

Example 128

Fluorescein-labeling of LNA oligomers. LNA oligomers (formula Z of Figure 2) AL16 (5´-d(**TGTGTGAAATTGTTA**T)-3´; LNA nucleotides in bold) and AL17 (5´-d(**ATAAAGTGTAAA**G)-3´; LNA nucleotides in bold) were succesfully labeled with fluorescein using the FluoroAmp T4 Kinase Green Oligonucleotide Labeling System as described by the manufacturer (Promega). Briefly, 16 nmol of either LNA-oligomer AL16 or AL17 was 5'-thiophosphate labelled in a 50 µl reaction buffer containing T4 kinase and γ-S-ATP. The reactions were incubated for 2 h at 37° C. The thio-phosphorylated LNA oligos were precipitated by the addition of 5µl of oligonucleotide precipitant (Promega) and 165 µl of ice cold (-20°C) 95 % ethanol. After

LNAs containing structure Z were particularly thoroughly examined (see Table 1). When three Z^T residues were incorporated into an oligonucleotide of mixed sequence the T_m´s obtained in NaCl buffer with both complementary DNA (10) and RNA (16) oligonucleotides were substantially higher (RNA: roughly 7 °C and DNA: roughly 5 °C per modification) than the T_m of the corresponding duplexes with unmodified oligonucleotides (1 and 8). Similar results were obtained with LNAs containing two Z^T residues and either one Z^G (21 and 24B) or Z^U (25), Z^C (69), $Z^{M\bullet C}$ (65), and Z^A (58) residues. When mismatches were introduced into the target RNA or DNA oligonucleotides the T_m of the LNA modified oligonucleotides in all cases dropped significantly (11-15A and 17; 18-20 and 22-24A; 26-31; 57 and 59-60; 63-64 and 66, and 67), unambiguously demonstrating that the LNA modified oligonucleotides hybridise to their target sequences obeying the Watson-Crick hydrogen bonding rules. In all cases the drop in T_m of the LNA modified oligonucleotides upon introduction of mismatches was equal to or greater than that of the corresponding unmodified oligonucleotides (2-7 and 9; 33-38), showing that the LNA modified oligonucleotide are at least as specific as their natural counterparts. A lowering of the ionic strength of the hybridisation buffer (from 10mM Na_2HPO_4, pH 7.0, 100mM NaCl, 0.1mM EDTA to 10mM Na_2HPO_4 pH 7.0, 0.1mM EDTA) lowers the T_m of the LNA modified oligonucleotides for their complementary DNA oligos (40,41) or RNA oligonucleotides (40A, 41A). A similar effect is observed with the unmodified oligonucleotides and its complementary DNA oligo (39) or RNA oligo (39A).

Addition of 3M tetrametylammoniumchlorid (TMAC) to the hybridisation buffer significantly increases the T_m of the LNA modified oligonucleotide for their complementary DNA oligos (10,21,25). Moreover, TMAC levels out the diffeneces in the T_m's of the different oligonucleotides which is observed in the NaCl buffer (lowest T_m in the NaCl buffer 44°C and highest 49°C as opposed to 56°C and 57°C in TMAC). Introduction of mismatches substantially decreases the T_m of the LNA modified oligonucleotides for their DNA targets (11-13, 18-20, and 26-28). A similar picture emerges with the unmodified reference oligonucleotides (1-4 and 32-35)

The data with the low salt buffer shows that LNA modified oligonucleotides exhibit a sensitivity to the ionic strength of the hybridisation buffer similar to normal

unmodifed oligonucleotides (Table 1, 42 and 43). The partly modified oligonucleotides containing monomers of structure **V** and **Y** behaved similarly to partly modified oligonucleotides containing Z^T and probably this is due to the homopolymer nature of the sequence as outlined above. Oligonucleotides containing X^T in all cases exhibited a much reduced T_m compared to the reference DNA oligonucleotides.

Example 130

A fully modified LNA oligonucleotide form stable hybrids with complementary DNA in both the anti-parallel and the parallel orientation. A full modified LNA oligonucleotide was hybridised to its complementary DNA in both the anti-parallel and the parallel orientation. Hybridisation solutions (1 mL) contained 10 mM Na_2HPO_4 (pH 7), 100 mM NaCl and 0.1 mM EDTA and 1 μM of each of the two olignucleotides. As shown in Table 1 both the anti-parallel (71) and the parallel binding orientation (77) produces stable duplexes. The anti-parallel is clearly the most stable of the two. However, even the parallel duplex is significantly more stable than the corresponding anti-parallel duplex of the unmodified DNA oligonucleotides (Table 1, 1).

Example 131

LNA monomers can be used to increase the affinity of RNA oligomers for their complementary nucleic acids. The thermostability of complexes between a 9-mer RNA oligonucleotide containing 3 LNA-T monomers (Z^T) and the complementary DNA or RNA oligonucleotides were measured spectrophotometrically. Hybridisation solutions (1 ml) containing 10mM Na_2HPO_4, pH 7.0, 100mM NaCl, 0.1mM EDTA and 1μM of each of the two oligonucleotides. Identical hybridisation mixtures using the unmodified RNA oligonucleotides were measured as references. As shown in Table 5 the LNA modified RNA oligonucleotide hybridises to both its complementary DNA (1) and RNA (3) oligonucleotide. As previously observed for LNA modified DNA oligonucleotides, the binding affinity of the LNA modified RNA oligonucleotide is strongest to the RNA complement (3). In both cases the affinity of the LNA modified RNA oligonucleotide is substantially higher than that of the unmodified controls (2 and 4). Table 5 also shows that the specificity towards both DNA and RNA targets are retained in LNA modified RNA oligonucleotides.

thioate oligonucleotide has been demonstrated. It can be anticipated that such constructs will display both Rnase H activity and nuclease resistance in addition to the LNA enhanced hybridisation characteristics.

Example 134

2'-Thio-LNA display nucleic acid recognition properties comparable with those of LNA (Monomer Z). The hybridisation conditions were as described in Example 132, however without EDTA. The results for the 2'-thio-LNAs (Table 8) clearly indicate a positive effect on the thermal stability of duplexes towards both DNA and RNA by the introduction of 2'-thio-LNA monomer U^S (The monomers correspond to formula Z of Figure 2 where the methyleneoxy bridge has been substituted with a methylenethio bridge). This effect ($\Delta T_m \sim +5$ °C / modification towards DNA; $\Delta T_m \sim +8$ °C / modification towards RNA) is comparable with that observed for parent LNA. The picture is complicated by the simultaneous introduction of two modifications (the 2'-thio functionality and uracil instead of thymine). However, as we have earlier observed identical melting temperatures for the LNA thymine and uracil monomers, and as the references containing 2'-deoxyuridine instead of thymidine, if anything, would be expected to display lower T_m values, the comparison is relevant.

Example 135

2'-Amino-LNA (Monomer Z^{TNH}) and 2'-Methylamino-LNA (Monomer Z^{TNMe}) display nucleic acid recognition properties comparable with those of parent LNA (Monomer Z). The hybridisation conditions were as described in Example 132, however without EDTA. The melting results for the 2'-amino-LNAs (Table 9) clearly indicate a positive effect on the thermal stability of duplexes towards DNA and RNA by introduction of either 2'-amino-LNA monomers T^{NH} or T^{NMe} (The monomers correspond to formula Z of Figure 2 where the methyleneoxy bridge has been substituted with a methyleneamino bridge or methylene-(N-methyl)amino bridge, respectively). This effect ($\Delta T_m \sim +3$ °C / modification towards DNA and $\Delta T_m \sim +6$ to $+8$ °C / modification towards RNA) is comparable to that of parent LNA. It is notheworthy, that the increased thermal affinity is also observed with an oligo composed of a mixture of 2'-alkylamino-LNA monomers and nonalkylated 2'-amino-LNA monomers.

relative signal intencities of the unmodified (lane 1,2), partly (lane 3,4) and fully modified oligos (lane 5,6) in the autoradiogram suggests that the more LNA nucleosides a standard DNA oligo contains the more efficiently it can be precipitated by salt/alcohol procedures. Thirdly, the similar positions of the signal in the autoradiogram of the unmodified, partly and fully modified oligos shows that incorporation of LNA nucleosides into a DNA oligo does not alter its electrophoretic mobility in polyacrylamide gels.

Example 138

3'-End labelling of LNA-containing oligonucleotides with terminal deoxynucleotidyl transferase. Oligonucleotides containing LNA monomers were 3'end-labelled using the enzyme terminal deoxynucleotidyl transferase. The sequence and extent of LNA modification were as follows (where LNA monomers are in bold):

Control	5' GGT GGT TTG TTT G 3'
(1)	5' GGT GGT **TTG** TTT G 3'
(2)	5' GGT GGT **TTG** TTT G 3'
(3)	5' **GGT GGT TTG TTT G** 3'

Oligonucleotide (50 pmol) was incubated with 250 µCi [α-^{32}P]ddATP (3000 Ci/mmol) and 100 Units terminal deoxynucleotidyl transferase in 250 µl 100mM cacodylate buffer pH 7.2, 2mM $CoCl_2$ and 0.2mM 2-mercaptoethanol at 37°C for 2 hours. The reaction was then stopped by adding formamide loading buffer and heating to 100°C for 5 min before placing on ice. Samples (0.2 pmol) were run on a 19% acrylamide gel containing 7M urea and the percentage incorporation of radioactivity into the oligonucleotide bands was quantified by means of a phosphorimager (Molecular Dynamics). The results show incorporation of radioactivity in all cases, including the oligonucleotide with a high LNA content: Control 94.9%, (1) 39.7%, (2) 83.7%, (3) 31.7%. We conclude that LNA modified oligos are substrates for the TdT enzyme.

Example 139

The ability of terminal deoxynucleotidyl transferase (TdT) to tail LNA modified oligonucleotides depends on the design of the oligomer. The following 15mer primers and a mixture of 8 to 32 base oligonucleotide markers were 5' end labelled with [γ ^{33}P] ATP and T4 polynucleotide kinase (where LNA monomers are in bold):

resulted in the primer being extended by one base and ~50% of this being extended by a further base. This result is very similar to that obtained with ribonucleotides and TdT. We conclude that LNA derived triphosphates can be recognised and incorporated into a DNA oligonucleotide by the TdT enzyme. This latter finding that LNA-TTP can bind to the polymerase underscores the possibility of successfully using LNA-monomer derivatives as nucleoside drugs.

Example 141

Exonuclease free Klenow fragment DNA polymerase I can incorporate LNA Adenosine, Cytosine, Guanosine and Uridine-5'-triphosphates (LNA ATP, LNA CTP, LNA GTP, LNA UTP) into a DNA strand. A primer extension assay was used to evaluate the LNA NTP's (see Example 123), ribonucleotides, as substrates for exonuclease free Klenow fragment DNA polymerase I (EFK). The assay used a ^{33}P 5' end labelled 15mer primer hybridised to one of four different 24mer templates. The sequences of the primer and templates are (LNA monomer in bold):

Primer 5' TGCATGTGCTGGAGA 3'

Template 1 3' **ACGTACACGACCTCT**ACCTTGCTA 5'

Template 2 3' **ACGTACACGACCTCT**CTTGATCAG 5'

Template 3 3' **ACGTACACGACCTCT**TGGCTAGTC 5'

Template 4 3' **ACGTACACGACCTCT**GAACTAGTC 5'

One picomole ^{33}P labelled primer was hybridised to 2 picomoles of template in x2 Klenow buffer. To this was added either 4 µM dNTPαS or 500 µM LNA NTP or a mixture of 4 µM dNTPαS and 500 µM LNA NTP. Two units of EFK DNA polymerase was added to each reaction. 2mU inorganic pyrophosphatase was added to each of the reactions. Primer plus template plus enzyme controls were also carried out. All reactions were carried out in a total volume of 20 µl. The reactions were incubated at 37°C for 3 min. Reactions were then stopped by the addition of 10 µl formamide EDTA stop solution. Reaction products were separated on a 19% polyacrylamide 7M urea gel and the product fragments sized by comparison with a ^{33}P labelled 8 to 32 base oligonucleotide ladder after exposure to Kodak Biomax autoradiography film.

Figure 20 shows the result with LNA-UTP using template 1. The tracks (1-12) correspond to the following reactions: Incorporation of LNA UTP by EFK. Lane 1 - Primer, template and enzyme. Lane 2 - plus dTTPαS. Lane 3 - plus LNA UTP. Lane 4 -

CTP is efficiently incorporated to give the +1 product on Template 4 (track 20). Extension of this product by dTTPαS is again slow (track 21). The addition of LNA GTP and dTTPαS to reactions on Template 1 results in the +2 product (track 16). Again this shows that the addition of a single LNA triphosphate is quite efficient, but that the addition of consecutive LNA triphosphates is slow.

Example 142

LNA monomers can be used to enhance the resistance of an oligonucleotide to digestion by exonuclease III. In order to test the resistance of the LNA containing oligonucleotides to Exonuclease III degradation the following reaction was performed. The following 15mer primers and 8 to 32 base oligonucleotide markers were 5' end labelled with [γ ^{33}P] ATP and T4 polynucleotide kinase (LNA monomer in bold):

P2 5'- GC ATG TGC TGG AGA T-3'

PZ2 5'- GC ATG TGC TGG AGA **T**-3'

Reactions were boiled for 5 min after labelling to remove any PNK activity. 8 picomoles of each primer was hybridised to 25 pmoles Template (sequence: 3'- ACG TAC ACG ACC TCT ACC TTG CTA-5') in x2 Klenow buffer. 10 Units of Exonuclease III was added to each of the reactions. Controls were also set up which had 1μl water added in place of the enzyme. The reactions were incubated at 37°C for 5 min. The reactions were stopped by the addition of 10μl formamide/EDTA stop solution. The reactions were heated at 95°C for 3 min before loading onto a 19% polyacrylamide 7M urea gel. The gel was fixed in 10% acetic acid/10% methanol before transferring to 3MM paper and drying. The dried gel was exposed to a phosphor screen for 3 hours. The phosphor screen was analysed on the Molecular Dynamics Storm 860 instrument using ImageQuant software. The phosphor screen analysis showed that in the absence of the enzyme the P2 full length band was 99% of the signal and PZ2 full length band was 96% of the signal. In the presence of the enzyme only 20% of the P2 full length product was left after the 5 minute incubation. However, 62% of the full length PZ2 product remained after the same treatment. This shows that a single LNA monomer at the 3' end of an oligonucleotide can enhance the resistance to degradation by exonuclease III.

10 µl of DIG-labelled amplicon 1 or amplicon 2 was mixed with 5 pmol of 5' biotinylated capture probe in 1xSSC (0.15 M NaCl, 15mM citrate, pH 7.0) in a total volume of 450 µl. The following capture probes were used: B-DNA1 (biotin-ATGCCTGCAGGTCGAC-3'; DNA probe specific for amplicon 1), B-DNA2 (biotin-GGTGGTTTGTTTG-3'; DNA probe specific for amplicon 2) and B-LNA2 (biotin-**GGTGGTTTGTTT**G-3', LNA nucleosides in bold; LNA probe specific for amplicon 2). Reactions were heated to 95°C for 5 min in order to denature amplicons and allowed to cool at 25°C for 15 min to facilitate hybridisation between the probe and the target amplicon strand. After hybridisation 190 µl of each reaction were transferred to a streptavidin coated micro plate (Pierce, cat. no.15124) and incubated for one hour at 37°C. After washing the plate with phosphate buffered saline (PBST, 0.15 M Na^+, pH 7.2, 0.05% Tween 20, 3x 300µl), 200 µl of peroxidase labelled anti- DIG antibodies were added (Boehringer Mannheim, diluted 1:1000 in PBST). Plates were incubated for 30 min at 37°C and washed (PBST, 3x 300µl). Wells were assayed for peroxidase activity by adding 100 µl of substrate solution (0.1 M citrate-phosphate buffer pH 5.0, 0.66mg/ml ortho-pheylenediamine dihydrochloride, 0.012% H_2O_2). The reaction was stopped after 8 min by adding 100 µl H_2SO_4 (0.5 M) and the absorbance at 492 nm was read in a micro plate reader. As shown in Figure 3, the unmodified bio-DNAs capture probes (B-DNA1 and B-DNA2) both behave as expected, *i.e.* they each capture only their target PCR amplicon. Compared to the B-DNA1 probe the B-DNA2 probe is rather inefficient in capturing its cognate amplicon. The capture efficiency of the B-DNA2 probe, however, can be dramatically improved by substituting 12 of its 13 DNA nucleosides by the corresponding LNA nucleosides. As shown in Figure 3 the use of the B-LNA2 probe in place of the B-DNA2 probe leads to a more that 10 fold increase in the sensitivity of the assay. At the same time the B-LNA2 retains the ability of the un-modified B-DNA2 to efficiently discriminate between the related and non-related amplicon, underscoring the excellent specificity of LNA-oligos. We conclude that 1) biotin covalently attached to an LNA modified oligo retains its ability to bind to streptavidin, 2) that LNA modified oligos works efficiently in a MTP based amplicon capture assay and that 3) LNA offers a means to dramatically improve the performance of standard DNA oligos in the affinity capture of PCR amplicons.

major importance in the development of efficient new drugs by the antisense, and in particular anti-gene approach.

Example 145

An LNA substituted oligo, immobilised on a solid surface function efficiently in the sequence specific capture of a PCR amplicon. Wells of a streptavidin coated micro-titer plate (Boehringer Mannheim) were incubated for 1 hour with either 5 pmol of the B-DNA2 probe (biotin-GGTGGTTTGTTTG-3´; DNA probe specific for amplicon 2) or the B-LNA2 probe (biotin-**GGTGGTTTGTTTG**-3´, LNA nucleosides in bold; LNA probe specific for amplicon 2) in a total volume of 100µl 1xSSC (0.15 M NaCl, 15mM citrate, pH 7.0). In total, four wells were incubated with the B-DNA2 probe, four wells with the B-LNA2 probe and four wells were incubated with buffer alone. After incubation the wells were washed three times with 1xSSC. DIG-labelled amplicon1(60µl) or amplicon2 (60µl) (prepared as in Example 143) were mixed with 540µl of 1 xSSC, heat denaturated at 95°C for 5 min., and transferred (100µl) to the micro plate wells. Two of the wells containing either B-DNA2, B-LNA2 or no capture probe received amplicon1 and two of the wells containing B-DNA2, B-LNA2 or no capture probe received amplicon2. After 1 hour at 37°C the plate was washed 3 times with phosphate buffered saline (PBST, 0.15 M Na^+, pH 7.2, 0.05% Tween 20, 3x 300µl) and 200 µl of peroxidase labelled anti- DIG antibodies were added (Boehringer Mannheim, diluted 1:1000 in PBST). Plates were incubated for 30 min at 37°C and washed 3 times with 300µl PBST. Wells were assayed for peroxidase activity by adding 100 µl of substrate solution (0.1 M citrate-phosphate buffer pH 5.0, 0.66mg/ml ortho-pheylenediamine dihydrochloride, 0.012% H_2O_2). The reaction was stopped after 6 min by adding 100 µl H_2SO_4 (0.5 M) and the absorbance at 492 nm was read in a micro plate reader. As shown in Figure 5, the LNA modified capture probe (B-LNA2) captures its specific amplicon (amplicon2) very efficiently and significantly better (approx. five fold increase in sensitivity) than the corresponding unmodified DNA capture probe (B-DNA2). No signal is obtained when the B-LNA2 probe is incubated with the unrelated amplicon (amplicon1) underscoring the exquisite specificity of the B-LNA2 probe. We conclude that LNA modified oligos function efficiently in the sequence specific capture of PCR amplicons when immobilised on a solid surface. We further conclude that the use of LNA modified oligos in place of standard DNA oligos provide for a better signal to noise ratio. Thus, LNA offers a

pmol of DNA Nras Cap A (biotin-5'-TTCCACAGCACAA-3'), LNA/DNA Nras Cap A (biotin-5'-TTCCA**CAGC**ACAA-3'), LNA Nras Cap A (biotin-5'-**TTCCACAGCACA**A-3'), DNA Nras Cap B (biotin-5'-AGAGCCGATAACA-3'), LNA/DNA Nras Cap B (biotin-5'-AGAG**CCGATA**ACA-3') or LNA Nras Cap B (biotin-5'-**AGAGCCGATAACA**-3'); LNA nucleosides in bold. The Nras Cap A capture probes capture amplicons Nras 910, Nras 600 and Nras 200. Nras Cap B capture probes capture specific amplicons Nras 910 and Nras 600. After incubation with the different capture probes, the wells were washed in 5 x SSCT and 5 µl native or denatured (95° C 5 min and 10 min on ice) DIG-labelled amplicons (Nras 910, Nras 600 or Nras 200) in 95 µl 1 x SSCT (0.15 M NaCl, 15 mM citrate, pH 7.0, 0.1% Tween 20) were added per well and incubated for 1 hour at 37°C. The wells were washed three times in phosphate buffered saline (1 x PBST, 0.15 M Na^+, pH 7.2, 0.05% Tween 20) and incubated 30 min at 37°C with 200 µl peroxidase labelled anti-DIG antibodies (Boehringer Mannheim, diluted 1:1000 in 1 x PBST). Finally the wells were washed three times in 1 x PBST and assayed for peroxidase activity by adding 100 µl of substrate solution (0.1 M citrate-phosphate buffer pH 5.0, 0.66 mg/ml ortho-pheylenediamine dihydrochloride, 0.012% H_2O_2) the reaction was stopped after 9 min by adding 100 µl 0.5 M H_2SO_4 and diluted 4 times in H_2SO_4 before the absorbance at 492 nm was read in a micro-titer plate reader. As shown in Figure 23A, capture probes spiked with 12 LNA nucleosides (LNA Nras Cap A and LNA Cap B) capture very efficiently the specific amplicons without prior denaturation (native amplicons). Capture probes spiked with 4 LNA nucleosides (LNA/DNA Nras Cap A and LNA/DNA Nras Cap B) capture the same amplicons with a lower efficiency and the DNA capture probes (DNA Nras Cap A and DNA Nras Cap B) do not capture the specific amplicons at all. The control amplicon, Nras 200, are not captured by the LNA Cap B or the LNA/DNA Nras Cap B probes demonstrating the exquisite specificity of the LNA spiked capture probes. Figure 23B shows the same experiment performed with denatured amplicons. Essentially the same picture emerges with the essential difference that capture efficiencies are generally increased. We conclude that LNA modified oligos containing mixed LNA nucleosides (A, T, G or C LNA nucleosides) function efficiently in sequence specific capture of PCR amplicons when immobilised on a solid surface. We further conclude that LNA offers a means to construct capture probes that will function efficiently in amplicon capture without prior denaturation i.e. capture by strand displacement. This ability facilitates a significant simplification of current amplicon detection formats based on DNA.

When M-MuLV reverse transcriptase is used (lanes 2) an extension product can be detected only in the case of the LNA-primer. The labelled LNA and DNA primer that have not been subjected to enzymatic elongation are present in lanes 1, 4 and 6. We conclude that the incorporation of LNA nucleosides into standard DNA oligos does not prevent recognition of the oligo/template duplex by nucleic acid polymerases. We further conclude that LNA modified oligos act as efficiently as primers as unmodified DNA oligos.

Example 148

LNA modified oligo functions as primers in target amplification processes. The ability of LNA modified oligos to act as primers in PCR amplification was analysed with three oligos differing only in the number of LNA nucleosides they contained: 4 LNA nucleosides (AL2 primer: 5´-GGTGGTTTGTTTG-3´, LNA nucleosides in bold), 1 LNA nucleoside (AL10 primer: 5´-GGTGGTTTGTTTG-3´, LNA nucleoside in bold) and no LNA nucleoside (FP2 primer: 5´-GGTGGTTTGTTTG-3´). The PCR reactions (100µl) contained either no template (control), 0.01ng, 0.1ng or 1ng of template (pUC19 plasmid), 0.2µM reverse primer (5´-GTGGTTCGCTCCAAGCTG-3´), 0.2µM of either the AL2, AL10 or FP2 forward primer, 200µM of dATP, dGTP, dCTP and dTTP, 10mM Tris-HCl pH 8.3, 1.5mM $MgCl_2$, 50mM KCl and 2.5U of the BM-Taq polymerase. A total of 50 cycles each consisting of 94°C 1min. - 45°C 1min. - 72°C 1.5min. were conducted (with an additional 2.5U of Taq polymerase added after the first 30 cycles) on a Techne Genius thermocycler. After the final cycle the reactions were incubated at 72°C 3min. and then at 4°C overnight. To 30µl of each reaction was added 6µl of loading buffer (0.25% (w/v) bromophenol blue and 40% (v/v) glycerol) and the samples (together with a Amplisize™ size marker) were loaded onto a 2% agarose gel and electrophoresed for 45min. at 150V. Finally, the gel was stained with ethidiumbromid and photographed. As shown in Figure 8 the PCR reactions using the unmodified forward primer FP2 and unmodified reverse primer generates detectable amplicons of the correct sizes with all amounts of template used (lane 9: 0.01ng template, lane 10: 0.1ng and lane 11: 1ng). No signal is obtained in the control reaction without template (lane 12). When the FP2 forward primer is replaced by the primer containing 1 central LNA nucleoside (AL10) amplicons are also detected with all amounts of template used (lane 5: 0.01ng, lane 6: 0.1ng and lane 7: 1ng). This clearly indicates that the AL10 primer sustains an exponential amplification. *i.e.* the

and one time phosphate buffered saline (PBST, 0.15 M Na^+, pH 7.2, 0.05% Tween 20),25ml PBST containing 0.06 µg/ml streptavidin conjugated horse radish peroxidase and 1 µg/ml streptavidin were added to the slide. The slide was incubated for 30 min and washed 4 times with 25ml PBST. The slide was visualised by using chemo-luminescent substrate (SuperSignal; Pierce) as described by the manufacturer and X-ray film (CL-XPosure film, Pierce 34075). As shown in Figure 9 both the AQ-DNA oligo and the AQ-LNA modified DNA oligo yields a clearly detectable signal. We conclude that anthraquinone linked LNA modified DNA oligos can be efficiently attached to a solid surface by irradiation and that oligos attached in this ways are able to hybridise to their complementary target DNA oligos.

Example 150

Hybridisation and detection on an array with different LNA modified Cy3-labelled 8mers. *Slide preparation:* Glass slides were aminosilanised using a 10% solution of amino propyl triethoxy silane in acetone followed by washing in acetone. The following oligonucleotides were spotted out onto the slides:

Oligo used	Oligo sequence	Pens 1 + 2 + 3	Sequence cf. probes
Seq. 3	5'-GTA TGG AG-3'	1pmol/µl	1 internal mismatch
Seq. 6	5'-GTA TGA AG-3'	1pmol/µl	match

Ten repeat spots, approximately 1 nl each spot, were performed for each oligonucleotide from each pen on each of 12 slides.

Probes (LNA monomers in bold):

a) Seq. No.aZ1 5'-Cy3-CTT CAT AC-3'

b) Seq. No.aZ2 5'-Cy3-CTT CAT AC-3'

c) Seq. No.aZ3 5'-Cy3-CTT CAT AC-3'

d) Seq. No.16 5'-Cy3-CTT CAT AC-3'

Slides and conditions for hybridisation:

Slides 1, 2 and 3 hybridised with aZ1 probe @ 300fmol/µl, 30fmol/µl, 3fmol/µl

Slides 4, 5 and 6 hybridised with aZ2 probe @ 300fmol/µl, 30fmol/µl, 3fmol/µl

Slides 7, 8 and 9 hybridised with aZ3 probe @ 300fmol/µl, 30fmol/µl, 3fmol/µl

Slides 10, 11 and 12 hybridised with seq. 16 probe @ 300fmol/µl, 30fmol/µl, 3fmol/µl

solution of amino propyl triethoxy silane in acetone followed by washing in acetone. The following oligonucleotides were spotted out at 1pmol/µl onto the slides:

Seq No.9 5'-GTGTGGAG-3'

Seq No.15 5'-GTGTGGAA-3'

Seq No.131 5'-GTGTGGAT-3'

Seq No.132 5'-GTGTGGAC-3'

Seq No.133 5'-ATGTGGAA-3'

Seq No.134 5'-CTGTGGAA-3'

Seq No.135 5'-TTGTGGAA-3'

Ten repeat spots, approximately 1 nl each spot, were performed for each oligonucleotide from each of 6 pens on each of 12 slides.

Probes (LNA monomers in bold):

DNA

Probe No.1: 5'-Cy3-TTCCACAC-3'

Probe No.2: 5'-Cy3-GTCCACAC-3'

Probe No.3: 5'-Cy3-ATCCACAC-3'

Probe No.4: 5'-Cy3-CTCCACAC-3'

Probe No.5: 5'-Cy3-TTCCACAT-3'

Probe No.6: 5'-Cy3-TTCCACAG-3'

LNA

Probe No.35Z-1: 5'-Cy3-**T**TCCACA**C**-3'

Probe No.35Z-2: 5'-Cy3-**G**TCCACA**C**-3'

Probe No.35Z-3: 5'-Cy3-**A**TCCACA**C**-3'

Probe No.35Z-4: 5'-Cy3-**C**TCCACA**C**-3'

Probe No.35Z-5: 5'-Cy3-**T**TCCACA**T**-3'

Probe No.35Z-6: 5'-Cy3-**T**TCCACA**G**-3'

Probes with LNA monomers are prefixed with 35Z- as part of the sequence number. Specific LNA monomers are indicated in italics/bold and are situated at the 3' and 5' ends of the LNA oligos.

Slides and conditions for hybridisation: Each probe sequence was hybridised on a separate slide, and all probe concentrations were 1fmol/µl. Each probe was diluted in hybridisation buffer (5 x SSC, 7% sodium lauryl sarcosine), of which 30µl was

Seq No.9 5'-GTGTGGAG-3'

Seq No.15 5'-GTGTGGAA-3'

Seq No.131 5'-GTGTGGAT-3'

Seq No.132 5'-GTGTGGAC-3'

Seq No.133 5'-ATGTGGAA-3'

Seq No.134 5'-CTGTGGAA-3'

Seq No.135 5'-TTGTGGAA-3'

Ten repeat spots, approximately 1 nl each spot, were performed for each oligonucleotide from each of 6 pens on each of 36 slides.

Probes: (LNA monomers in bold):

DNA:

Probe No.1: 5'-Cy3-TTCCACAC-3'

Probe No.2: 5'-Cy3-GTCCACAC-3'

Probe No.3: 5'-Cy3-ATCCACAC-3'

Probe No.4: 5'-Cy3-CTCCACAC-3'

Probe No.5: 5'-Cy3-TTCCACAT-3'

Probe No.6: 5'-Cy3-TTCCACAG-3'

AT LNA:

Probe No.ATZ-1: 5'-Cy3-**TTCCACAC**-3'

Probe No.ATZ-2: 5'-Cy3-**GTCCACAC**-3'

Probe No.ATZ-3: 5'-Cy3-**ATCCACAC**-3'

Probe No.ATZ-4: 5'-Cy3-**CTCCACAC**-3'

Probe No.ATZ-5: 5'-Cy3-**TTCCACAT**-3'

Probe No.ATZ-6: 5'-Cy3-**TTCCACAG**-3'

All LNA:

Probe No.AllZ-1: 5'-Cy3-**TTCCACAC**-3'

Probe No.AllZ-2: 5'-Cy3-**GTCCACAC**-3'

Probe No.AllZ-3: 5'-Cy3-**ATCCACAC**-3'

The oligos with LNA modifications worked very well, and the mismatches that were the most difficult to discriminate were;

Probe 1 to target 135 = CT mismatch

Probe 2 to target 131 = GT mismatch

Probe 3 to target 15 = AA mismatch

Probe 4 to target 131 = CT mismatch

Probe 5 to target 135 = TT mismatch

Probe 6 to target 135 = GT mismatch

Probe 6 to target 133 = GA mismatch

The AT LNA oligos gave good discrimination where these mismatch spot intensities were typically at the most 50% of the intensity of the match spots. For these mismatches, the all LNA oligos gave mismatch spot intensities about 50 to 70% of the match spot intensities. Overall, LNA modifications allows the use of higher temperatures for hybridizations and washes, and end mismatches can be discriminated. These results are at least as good as those from DNA probes hybridised at 4°C (see example 151).

Example 153

Use of [α^{33}P] ddNTP's and ThermoSequenase™ DNA Polymerase to Sequence DNA Templates Containing LNA T Monomers. Radiolabelled terminator sequencing reactions were set up in order to test the ability of the LNA T monomer to be accepted as a template for DNA polymerases. The 15mer primer (sequence: 5'- TGC ATG TGC TGG AGA -3') was used to prime the following short oligonucleotide sequences (LNA monomer in bold):

Template 1 3'- ACG TAC ACG ACC TCT ACC TTG CTA -5'

TemplateTZ1 3'- ACG TAC ACG ACC TCT ACC TTG CTA -5'

The following reaction mixes were made:

Template 1 mix:

2µl x16 ThermoSequenase Buffer

the template sequence 3'-ACC TTG CTA- 5'. This shows that a single LNA T monomer can act as a template for DNA polymerases. The LNA T monomer is specifically copied as "T" with ddATP being incorporated.

Therapeutic applications

Example 154

LNA modified oligos can be transferred into cells. Experiment with radiolabelled LNA oligos. 10 pmol of a oligodeoxynucleotide (ODN) (ODN#10: 5'-TTA ACG TAG GTG CTG GAC TTG TCG CTG TTG TAC TT-3', a 35-mer complementary to human Cathepsin D) and 10 pmoles of two LNA oligos: AL16 (5'-d(**TGT GTG AAA TTG TTA** T)-3', LNA nucleosides in bold) and AL17 (5'-d(**ATA AAG TGT AAA** G)-3', LNA nucleosides in bold) were mixed with T4 polynucleotide Kinase (10 units, BRL cat. no. 510-8004SA), 5 µl gamma-^{32}P-ATP 5000 Ci/mmol, 10 uCi/µl (Amersham) in kinase buffer (50 mM Tris/HCl pH 7,6, 10 mM $MgCl_2$, 5 mM DTT, 0.1 mM EDTA). The samples were incubated for 45 min at 37°C and afterwards heated to 68°C for 10 min, and then moved to +0 °C. Unincorporated nucleotides were removed by passage over Chroma Spin TE-10 columns (Clontech cat. no. K1320-1). The yields were $5x10^5$ cpm/µl , $2x10^5$ cpm/µl and $0.8x10^5$ cpm/µl for ODN#10, AL16 and AL17, respectively. MCF-7 human breast cancer cells originally obtained from the Human Cell Culture Bank (Mason Research Institute, Rockville) were cultured in DME/F12 culture medium (1:1) supplemented with 1% heat inactivated fetal calf serum (Gibco BRL), 6 ng/ml bovine insulin (Novo) and 2.5 mM glutamax (Life Technologies) in 25 cm^2 cell culture flasks (Nunclon, NUNC) and incubated in a humified incubator at 37°C, 5%CO_2, 20%O_2, 75%N_2. The MCF-7 cells were approximately 40% confluent at the time of the experiment. A small amount (less than 0.1 pmol) of the kinased oligos were mixed with 1.5 µg pEGFP-NI plasmid (Clontech cat. no. 60851) and mixed with 100 µl diluted FuGENE6 transfection agent (Boehringer Mannheim cat no. 1 814 443), dilution: 5µl FuGENE6 in 95 µl DME/F12 culture medium without serum. The FuGENE6/DNA/oligo-mixture were added directly to the culture medium (5 ml) of adherent growing MCF-7 cells and incubated with the cells for 18 hours, closely following the manufacturers directions. Three types of experiments were set up. 1) ODN#10 + pEGFP-NI; 2) AL16 + pEGFP-NI; 3) AL17 + pEGFP-NI. Cellular uptake of DNA/LNA material were studied by removing FuGENE6/DNA/oligo-mixture containing

Table: Oligonucleotides tested

Name	Sequence (LNA monomers in bold)	Characteristics
AL16	5'-**TGT GTG AAA TTG TTA** T-3'	LNA, enzym. FITC-labeled
AL17	5'-**ATA AAG TGT AAA** G-3'	LNA, enzym. FITC-labeled
EQ3009-01	5'-**TGC CTG CAG GTC GAC** T-3'	LNA-FITC-labeled
EQ3008-01	5'-TGC CTG CAG GTC GAC T-3'	DNA-FITC-labeled

AL16 and AL17 were enzymatically labelled with FITC as described in Example 128. EQ3009-01 and EQ3008-01 were labelled with FITC by standard solid phase chemistry. Three transfection agents were tested: FuGENE-6 (Boehringer Mannheim cat. no. 1 814 443), SuperFect (Quiagen cat. no. 301305) and Lipofectin (GibcoBRL cat. no. 18292-011). Human MCF-7 breast cancer cells were cultured as described previously (Example 154). Three days before the experiments the cells were seeded at a cell density of approx. 0.8×10^4 cells per cm^2. Depending on the type of experiment the MCF-7 cells were seeded in standard T25 flasks (Nunc, LifeTechnologies cat. no. 163371A), 24 wells multidish (Nunc, LifeTechnologies cat. no. 143982A) or slide flasks (Nunc, LifeTechnologies cat. no. 170920A). The experiments were performed when cells were 30 - 40 % confluent. Cellular uptake of LNA and DNA was studied at serum-free conditions, i.e. the normal serum containing DME/F12 medium was removed and replaced with DME/F12 without serum before the transfection-mixture was added to the cells. Under these conditions SuperFect proved to be toxic to the MCF-7 cells. Transfection mixtures consisting of SuperFect and either plasmid DNA (pEGFP-N1, Clontech cat. no. 6085-1), oligo DNA or oligo LNA was equally toxic to MCF-7 cells. In contrast to SuperFect, FuGene6 and Lipofectin worked well with plasmid DNA (pEGFP-N1). However, only lipofectin was capable of efficient delivery of oligonucleotides to living MCF-7. Briefly, efficient delivery of FITC-labelled LNA and DNA to MCF-7 cells was obtained by culturing the cells in DME/F12 with 1% FCS to approx. 40% confluence. The Lipofectin reagent was then diluted 40 X in DME/F12 medium without serum and combined with the oligo to a concentration of 750 nM

nucleosides in bold) and AL17 (5'-**ATA AAG TGT AAA** G-3', LNA nucleosides in bold) were labeled with fluorescein as described in Example 128. MCF-7 human breast cancer cells were cultured as described in Example 154. Three types of experiments were set up. 1) approximately 1.5 μg FITC-labelled AL16; 2) approximately 1.5 μg FITC-labelled AL17; and 3) approximately 0.75 μg FITC-labelled AL16 and 0.75 μg pRSVβgal plasmid (a plasmid expressing the bacterial lac Z gene coded enzyme β-galactosidase, Tulchinsky et. al. (1992) PNAS, **89**, 9146-50). The two LNA oligos and the LNA-plasmid mix were mixed with FuGENE6 and added to MCF-7 cells as described in Example 154. After incubation for 18 hours cellular uptake of the LNA oligos were assessed by fluorescence microscopy of the cell cultures. A part of the treated cells contained green fluorescent material (see Figure 16), indicating that cells take up the fluorescein labelled LNA. The fluorescein labelled AL16 appeared superior to fluorescein labelled AL17 in this respect. After fluorescence microscopy the culture medium were removed from the cells treated both with fluorescein labelled AL16 and pRSVβgal. The cells were washed once with PBS, fixed in 2% (v/v) formaldehyde, 0.2% (v/v) glutaraldehyde at 4°C for 5 min and β-galactosidase containing cells were stained blue with X-gal (5-bromo-4-chloro-3-indoyl β-D-galactopyranosid) which turns from colorless to blue in the presence of β-galactosidase activity. The X-gal staining showed that the pRSVβgal effectively had been transferred into cells. We conclude that the fluorescein LNA oligos were taken up by the cells.

Example 157

LNA modified oligos are relatively stable under cell culture conditions. Following fluorescence microscopy as described in Example 156 cells treated only with the fluorescein labelled AL16 LNA were allowed to incubate for an additional 3 days. During this period of time the number of green fluorescent cells appeared unaltered. We conclude that fluorescein labelled LNA oligos has a good stability under the conditions prevailing in cell culture.

Example 158

Blockade by Antisense Locked Nucleic Acids (LNA) of [D-Ala2]Deltorphin-Induced Antinociception in the Warm Water Tail Flick Test in Conscious Rats. Male Sprague-Dawley rats (300 g) were implanted with an intrathecal (i.th). polyethylene catheter and allowed to recover for at least 5 days before start of injections (including

(6 ml/g of support). To this mixture, triethylamine (16 microliter/g of support) was added and the mixture was kept on a shaker at 150 rpm overnight. Support was filtered, washed with methanol (3 x 10 ml/g of support) and dichloromethane (3 x 10 ml/g of support). After air drying, support was dried *in vacuo* for 0.5h. To this 6% DMAP in anhydrous acetonitrile (Cap A, ~ 3 ml/g of support) and a mixture of 20% acetic anhydride/ 30% 2,4,6-collidine/ 50% acetonitrile (Cap B, ~ 3 ml/g of support) were added. The micture was kept on shaker for 5h. Support was filtered, washed with anhydrous dichloromethane (2 x 10 ml/g of support) and dried as above. It was resuspended in a mixture of Cap A and Cap B (total vol. 6 ml/g of support) and kept on shaker overnight. Support was filtered, washed with methanol (6 x 10 ml/g of support), dichloromethane (3 x 10 ml/g of support) and dried in air. It was further dried *in vacuo* for 5-6h. Loading was determined by dimethoxytrityl assay and was found to be approx. 40 µmol/g.

Example 160

First Strand cDNA Synthesis Using Poly dT Primers Containing LNA T monomers.

Reactions were set up in order to test the ability of poly dT primers containing LNA T residues to prime 1st strand cDNA synthesis. The following poly dT primers were tested (LNA monomers are in bold):

RTZ1 5'-**TTT TTT TTT TTT** TT-3'

RTZ2 5'-**TTT TTT TTT TTT** TT-3'

RTZ3 5'-**TTT TTT TTT TTT** TT-3'

RTZ4 5'-**TTT TTT TTT TTT** TT-3'

RTZ5 5'-**TTT TTT TTT** T-3'

Anchored poly dT primer from RPK0140 kit Cy Dye cDNA labelling kit (Amersham Pharmacia Biotech) was as a control.

Reactions were set up as follows for each of the primers above:

1µl	Arabidopsis mRNA 0.5µg/µl
2µl	poly dT primer 8pmoles/µl
4µl	x5 AMV Reverse Transcriptase buffer
1µl	Water
8µl	Total volume

Table of Oligo Binding Data

Steps	T9 oligo A_{260} units	T16 oligos A_{260} units	LNA T9 oligo A_{260} units	No oligo Control
Oligo reacted	14.7 (200nM)	26.0 (200 nM)	14.7 (200 nM)	0
Unbound oligo	5.50	10.43	4.20	-
∴Bound oligo	9.20	15.57	10.50	-
% Bound	62.6%	59.9%	71.4%	-

Oligo bound resins were divided into two portions (~25 mg resin each) for poly (rA) binding analysis in duplicate. Poly (rA) Pharmacia #27-4110-01 (dissolved at 28.2 A_{260} units/ml in binding buffer) was used for binding. Five (5) A_{260} units were bound to duplicate 25 mg portions of each oligo bound resin per SOP QC 5543. Unbound "breakthrough" poly (rA) was quantitated by A_{260} absorbance and used to calculate bound. The fate of the bound poly (rA) was tracked through Low salt buffer wash and several elutions. As shown in Table 10 both the LNA and DNA coated beads function efficiently in the capture of poly (rA) target molecules. The LNA coated beads, however, bind the poly (rA) target much more tightly than the DNA coated beads as evidenced by the poly (rA) elution profiles of the different beads. We conclude that 1) an LNA T9 oligo is efficient in the capture of RNA molecules containing a strech of A residues and that 2) the captured RNA molecules are bound much more tightly to the LNA T9 oligo beads than to the control DNA T9 and DNA T16 oligo.

Table 1 (cont.)

Oligo	Target	T_m No.	T_m (°C) Na_2HPO_4/EDTA	T_m (°C) Na_2HPO_4/NaCl/EDTA	T_m (°C) Na_2HPO_4/TMAC
5'-d(GTGAGATGC)-3'	5'-d(GCATATCAC)-3'	18		26	39
	5'-d(GCATTTCAC)-3'	19		33	44
	5'-d(GCATGTCAC)-3'	20		28	38
	5'-d(GCATCTCAC)-3'	21		49	57
	5'-d(GCATAACAC)-3'	22		<15	
	5'-d(GCATAGCAC)-3'	23		<15	
	5'-d(GCATACCAC)-3'	24		<15	
	5'-(GCAUAUCAC)-3'	24A		34	
	5'-(GCAUCUCAC)-3'	24B		59	
5'-d(GTGAUATGC)-3'	5'-d(GCATATCAC)-3'	25		44	56
	5'-d(GCATTTCAC)-3'	26		25	44
	5'-d(GCATGTCAC)-3'	27		32	43
	5'-d(GCATCTCAC)-3'	28		24	37
	5'-d(GCATAACAC)-3'	29		27	
	5'-d(GCATAGCAC)-3'	30		28	
	5'-d(GCATACCAC)-3'	31		20	
5'-d(GTGAGATGC)-3'	5'-d(GCATATCAC)-3'	32		17	34
	5'-d(GCATTTCAC)-3'	33		16	30
	5'-d(GCATGTCAC)-3'	34		15	28
	5'-d(GCATCTCAC)-3'	35		33	44
	5'-d(GCATAACAC)-3'	36		9.0	
	5'-d(GCATAGCAC)-3'	37		<5	
	5'-d(GCATACCAC)-3'	38		<5	
	5'-(GCAUCUCAC)-3'	38A		33	

Table 1 (cont.)

Oligo	Target	T_m No.	T_m (°C) Na_2HPO_4/EDTA	T_m (°C) Na_2HPO_4/NaCl/EDTA	T_m (°C) Na_2HPO_4/TMAC
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAAA)-3'	48		42	
	5'-(AAAAAAAAAAAAAAA)-3'	49		52	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAAA)-3'	50		47	
	5'-(AAAAAAAAAAAAAAA)-3'	51		53	
5'-d(TTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAAA)-3'	52		80	
	5'-(AAAAAAAAAAAAAAA)-3'	53		70	
	5'-d(AAAACAAAA)-3'	54		63	
	5'-d(AAAAGAAAA)-3'	55		55	
	5'-d(AAAATAAAA)-3'	56		65	
5'-d(GTGAAATGC)-3'					
	5'-d(GCATATCAC)-3'	57		26	
	5'-d(GCATTTCAC)-3'	58		45	
	5'-d(GCATGTCAC)-3'	59		23	
	5'-d(GCATCTCAC)-3'	60		25	
5'-d(GTGA^{Me}CATGC)-3'					
	5'-d(GCATATCAC)-3'	61		<15	
5'-d(GTGA^{Me}CATGC)-3'					
	5'-d(GCATATCAC)-3'	63		32	
	5'-d(GCATTTCAC)-3'	64		27	
5'-d(GCATGTCAC)-3'		65		53	
	5'-d(GCATCTCAC)-3'	66		32	

Table 2
Monomer V

Oligo	Target	T_m No.	T_m (°C) Na_2HPO_4/EDTA	T_m (°C) Na_2HPO_4/NaCl/EDTA	T_m (°C) Na_2HPO_4/TMAC
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			32	
	5'-(AAAAAAAAAAAAAA)-3'			27	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			31	
	5'-(AAAAAAAAAAAAAA)-3'			28	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			30	
	5'-(AAAAAAAAAAAAAA)-3'			23	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			23	
	5'-(AAAAAAAAAAAAAA)-3'			31	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			23	
	5'-(AAAAAAAAAAAAAA)-3'			16	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			<10	
	5'-(AAAAAAAAAAAAAA)-3'			42	
	5'-(AAAAAAGAAAAAAA)-3'			37	
5'-d(GTGATATGC)-3'					
	5'-d(GCATATCAC)-3'			26	
	5'-(GCAUAUCAC)-3'			27	

Table 4
Monomer Y

Oligo	Target	T_m No.	T_m (°C) Na_2HPO_4/EDTA	T_m (°C) Na_2HPO_4/NaCl/EDTA	T_m (°C) Na_2HPO_4/TMAC
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			36	
	5'-(AAAAAAAAAAAAAA)-3'			37	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			35	
	5'-(AAAAAAAAAAAAAA)-3'			37	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			35	
	5'-(AAAAAAAAAAAAAA)-3'			36	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			32	
	5'-(AAAAAAAAAAAAAA)-3'			33	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			36	
	5'-(AAAAAAAAAAAAAA)-3'			36	
5'-d(TTTTTTTTTTTTTT)-3'					
	5'-d(AAAAAAAAAAAAAA)-3'			58	
	5'-(AAAAAAAAAAAAAA)-3'			58	

Table 6
Monomer Z

Oligo	Target	T_m No.	Melting temperature (T_m/°C)
5'-d(GTGATATGC)-3'	5'-d(GCATATCAC)-3'	1	28
5'-d(GTGATATGC)-3'	5'-d(GCATATCAC)-3'	2	44
5'-d(GTGATATGC)-3'	5'-d(GCATATCAC)-3'	3	40
5'-d(GTGATATGC)-3'	5'-d(GCATATCAC)-3'	4	63
5'-r(GTGATATGC)-3'	5'-d(GCATATCAC)-3'	5	74
5'-(GTGATATG^{Me}C)-3'	5'-d(GCATATCAC)-3'	6	85

Table 7
Monomer Z (all-phosphoromonothioate oligonucleotides)

Oligo	Target	T_m No.	Melting temperature (T_m/°C)
5'-d($G^ST^SG^SA^ST^SA^ST^SG^SC$)-3'	5'-d(GCATATCAC)-3'	1	21
5'-d($G^ST^SG^SA^ST^SA^ST^SG^SC$)-3'	5'-r(GCAUAUCAC)-3'	2	17
5'-d($G^ST^SG^SA^ST^SA^ST^SG^SC$)-3'	5'-d(GCATATCAC)-3'	3	41
5'-d($G^ST^SG^SA^ST^SA^ST^SG^SC$)-3'	5'-r(GCAUAUCAC)-3'	4	47

Table 10

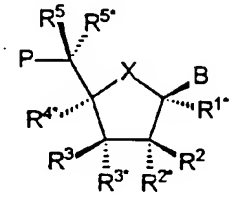
Steps	T9 oligo A_{260} units	T16 oligos A_{260} units	LNA T9 oligo A_{260} units	No oligo Control
poly (rA) added	5.0/5.0	5.0/5.0	5.0/5.0	5.0/5.0
poly (rA) breakthrough	1.75/1.61	1.84/1.78	1.83/1.82	5.09/5.14
∴poly (rA) bound	3.25/3.39	3.16/3.22	3.17/3.18	0.0/0.0
% poly (rA) bound	65.0%/67.8%	63.2%/64.4%	63.4%/63.6%	0.0%/0.0%
Low Salt Wash/Elute	0.24/0.24	0.11/0.12	.053/.055	0.14/0.13
TE Elute 15 min RT	2.37/2.72	0.83/0.93	0.02/0.04	0.01/0.02
TE Elute O.N. RT	0.38/0.37	1.76/1.69	0.11/0.07	.003/.004
TE Elute 30 min 65°C	.047/.040	0.38/0.46	1.62/1.70	.005/.004
10 mM Tris pH 10 Elute	.002/.002	0.03/0.03	0.10/0.10	0.01/0.01
1 mM HCl pH 4.0 Elute	0.07/0.06	0.06/0.04	0.26/0.23	0.01/0.01
Ave. A_{260} Recovered	3.20	3.14	2.18	-
Ave. % A_{260} Recovered	96.4%	98.4%	68.7%	-

formyl, aryl, aryloxy-carbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxy-carbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, azido, sulphanyl, C_{1-6}-alkylthio, halogen, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, where aryl and heteroaryl may be optionally substituted, and where two geminal substituents R^a and R^b together may designate optionally substituted methylene (=CH_2), and wherein two non-geminal or geminal substitutents selected from R^a, R^b, and any of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, R^{5*}, R^6 and R^{6*}, R^7, and R^{7*} which are present and not involved in P, P* or the biradical(s) together may form an associated biradical selected from biradicals of the same kind as defined before; said pair(s) of non-geminal substituents thereby forming a mono- or bicyclic entity together with (i) the atoms to which said non-geminal substituents are bound and (ii) any intervening atoms; and

each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{4*}, R^5, R^{5*}, R^6 and R^{6*}, R^7, and R^{7*} which are present and not involved in P, P* or the biradical(s), is independently selected from hydrogen, optionally substituted C_{1-12}-alkyl, optionally substituted C_{2-12}-alkenyl, optionally substituted C_{2-12}-alkynyl, hydroxy, C_{1-12}-alkoxy, C_{2-12}-alkenyloxy, carboxy, C_{1-12}-alkoxycarbonyl, C_{1-12}-alkylcarbonyl, formyl, aryl, aryloxy-carbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxy-carbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, azido, sulphanyl, C_{1-6}-alkylthio, halogen, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, where aryl and heteroaryl may be optionally substituted, and where two geminal substituents together may designate oxo, thioxo, imino, or optionally substituted methylene, or together may form a spiro biradical consisting of a 1-5 carbon atom(s) alkylene chain which is optionally interrupted and/or terminated by one or more heteroatoms/groups selected from -O-, -S-, and -(NR^N)- where R^N is

5. An oligomer according to any of the claims 1-4, wherein one of the substituents R^3 and R^{3*} designates P^*.

6. An oligomer according to any of the claims 1-5, wherein the LNA(s) has/have the following formula Ia



Ia

wherein P, P^*, B, X, R^{1*}, R^2, R^{2*}, R^3, R^{4*}, R^5, and R^{5*} are as defined in claims 1-5.

7. An oligomer according to claim 6, wherein R^{3*} designates P^*.

8. An oligomer according to any of the claims 1-7, comprising one biradical constituted by a pair of (two) non-geminal substituents.

9. An oligomer according to any of the claims 1-8, wherein X is selected from -(CR^6R^{6*})-, -O-, -S-, and -N(R^{N*})-, preferably -O-, -S-, and -N(R^{N*})-, in particular -O-.

10. An oligomer according to any of the claims 1-9, wherein the biradical(s) constituted by pair(s) of non-geminal substituents is/are selected from -(CR^*R^*)$_r$-Y-(CR^*R^*)$_s$-, -(CR^*R^*)$_r$-Y-(CR^*R^*)$_s$-Y-, -Y-(CR^*R^*)$_{r+s}$-Y-, -Y-(CR^*R^*)$_r$-Y-(CR^*R^*)$_s$-, -(CR^*R^*)$_{r+s}$-, -Y-, -Y-Y-, wherein each Y is independently selected from -O-, -S-, -Si(R^*)$_2$-, -N(R^*)-, >C=O, -C(=O)-N(R^*)-, and -N(R^*)-C(=O)-, each R^* is independently selected from hydrogen, halogen, azido, cyano, nitro, hydroxy, mercapto, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R^* may together designate a double bond, and each of r and s is 0-4 with the proviso that the sum r+s is 1-5.

(iii) R^{2*} and R^3 together designate a biradical selected from -O-, $-(CR^*R^*)_{r+s}-$, $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, and $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$;

(iv) R^3 and R^{4*} together designate a biradical selected from $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, and $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$;

(v) R^3 and R^5 together designate a biradical selected from $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, and $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$; or

(vi) R^{1*} and R^{4*} together designate a biradical selected from $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, and $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$;

(vii) R^{1*} and R^{2*} together designate a biradical selected from $-(CR^*R^*)_r-O-(CR^*R^*)_s-$, $-(CR^*R^*)_r-S-(CR^*R^*)_s-$, and $-(CR^*R^*)_r-N(R^*)-(CR^*R^*)_s-$;

wherein each of r and s is 0-3 with the proviso that the sum r+s is 1-4, and where X is selected from -O-, -S-, and $-N(R^H)-$ where R^H designates hydrogen or C_{1-4}-alkyl.

14. An oligomer according to claim 13, wherein R^{3*} designates P^*.

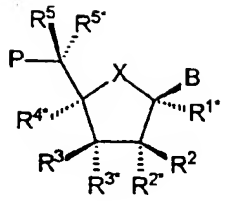
15. An oligomer according to claim 14, wherein R^{2*} and R^{4*} together designate a biradical.

16. An oligomer according to claim 15, wherein X is O, R^2 is selected from hydrogen, hydroxy, and optionally substituted C_{1-6}-alkoxy, and R^{1*}, R^3, R^5, and R^{5*} designate hydrogen.

17. An oligomer according to claim 16, wherein the biradical is selected from –O-, $-(CH_2)_{0-1}-O-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-S-(CH_2)_{1-3}-$, and $-(CH_2)_{0-1}-N(R^N)-(CH_2)_{1-3}-$.

18. An oligomer according to claim 17, wherein the biradical is selected from $-O-CH_2-$, $-S-CH_2-$ and $-N(R^N)-CH_2-$.

19 An oligomer according to any of the claims 15-18, wherein B is selected from nucleobases.



Ia

wherein X is -O-;

B is selected from nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands;

P designates the radical position for an internucleoside linkage to a succeeding monomer, or a 5'-terminal group, such internucleoside linkage or 5'-terminal group optionally including the substituent R^5;

R^{3*} is a group P* which designates an internucleoside linkage to a preceding monomer, or a 3'-terminal group;

R^{2*} and R^{4*} together designate a biradical selected from -O-, -S-, -N(R^*)-, -(CR^*R^*)$_{r+s+1}$-, -(CR^*R^*)$_r$-O-(CR^*R^*)$_s$-, -(CR^*R^*)$_r$-S-(CR^*R^*)$_s$-, -(CR^*R^*)$_r$-N(R^*)-(CR^*R^*)$_s$-, -O-(CR^*R^*)$_{r+s}$-O-, -S-(CR^*R^*)$_{r+s}$-O-, -O-(CR^*R^*)$_{r+s}$-S-, -N(R^*)-(CR^*R^*)$_{r+s}$-O-, -O-(CR^*R^*)$_{r+s}$-N(R^*)-, -S-(CR^*R^*)$_{r+s}$-S-, -N(R^*)-(CR^*R^*)$_{r+s}$-N(R^*)-, -N(R^*)-(CR^*R^*)$_{r+s}$-S-, and -S-(CR^*R^*)$_{r+s}$-N(R^*)-; wherein each R^* is independently selected from hydrogen, halogen, azido, cyano, nitro, hydroxy, mercapto, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R^* may together designate a double bond, and each of r and s is 0-3 with the proviso that the sum r+s is 1-4;each of the substituents R^{1*}, R^2, R^3, R^5, and R^{5*} is independently selected from hydrogen, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, hydroxy, C_{1-6}-alkoxy, C_{2-6}-alkenyloxy, carboxy, C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, azido, C_{1-6}-alkanoyloxy, sulphono, sulphanyl, C_{1-6}-alkylthio, DNA intercalators, photochemically active groups,

where R^H is selected form hydrogen and C_{1-4}-alkyl, and R'' is selected from C_{1-6}-alkyl and phenyl.

37. An oligomer according to claim 36, wherein any internucleoside linkage of the LNA(s) is selected from -CH_2-CH_2-CH_2-, -CH_2-CO-CH_2-, -CH_2-CHOH-CH_2-, -O-CH_2-O-, -O-CH_2-CH_2-, -O-CH_2-CH=, -CH_2-CH_2-O-, -NR^H-CH_2-CH_2-, -CH_2-CH_2-NR^H-, -CH_2-NR^H-CH_2-, -O-CH_2-CH_2-NR^H-, -NR^H-CO-O-, -NR^H-CO-NR^H-, -NR^H-CS-NR^H-, -NR^H-C(=NR^H)-NR^H-, -NR^H-CO-CH_2-NR^H-, -O-CO-O-, -O-CO-CH_2-O-, -O-CH_2-CO-O-, -CH_2-CO-NR^H-, -O-CO-NR^H-, -NR^H-CO-CH_2-, -O-CH_2-CO-NR^H-, -O-CH_2-CH_2-NR^H-, -CH=N-O-, -CH_2-NR^H-O-, -CH_2-O-N=, -CH_2-O-NR^H-, -CO-NR^H-CH_2-, -CH_2-NR^H-O-, -CH_2-NR^H-CO-, -O-NR^H-CH_2-, -O-NR^H-, -O-CH_2-S-, -S-CH_2-O-, -CH_2-CH_2-S-, -O-CH_2-CH_2-S-, -S-CH_2-CH=, -S-CH_2-CH_2-, -S-CH_2-CH_2-O-, -S-CH_2-CH_2-S-, -CH_2-S-CH_2-, -CH_2-SO-CH_2-, -CH_2-SO_2-CH_2-, -O-SO-O-, -O-S(O)$_2$-O-, -O-S(O)$_2$-CH_2-, -O-S(O)$_2$-NR^H-, -NR^H-S(O)$_2$-CH_2-, -O-S(O)$_2$-CH_2-, -O-P(O)$_2$-O-, -O-P(O,S)-O-, -O-P(S)$_2$-O-, -S-P(O)$_2$-O-, -S-P(O,S)-O-, -S-P(S)$_2$-O-, -O-P(O)$_2$-S-, -O-P(O,S)-S-, -O-P(S)$_2$-S-, -S-P(O)$_2$-S-, -S-P(O,S)-S-, -S-P(S)$_2$-S-, -O-PO(R'')-O-, -O-PO(OCH_3)-O-, -O-PO(BH_3)-O-, -O-PO(NHR^N)-O-, -O-P(O)$_2$-NR^H-, -NR^H-P(O)$_2$-O-, -O-P(O,NR^H)-O-, and -O-Si(R'')$_2$-O-.

38. An oligomer according to claim 37, wherein any internucleoside linkage of the LNA(s) is selected from -CH_2-CO-NR^H-, -CH_2-NR^H-O-, -S-CH_2-O-, -O-P(O)$_2$-O-, -O-P(O,S)-O-, -O-P(S)$_2$-O-, -NR^H-P(O)$_2$-O-, -O-P(O,NR^H)-O-, -O-PO(R'')-O-, -O-PO(CH_3)-O-, and -O-PO(NHR^N)-O-, where R^H is selected form hydrogen and C_{1-4}-alkyl, and R'' is selected from C_{1-6}-alkyl and phenyl.

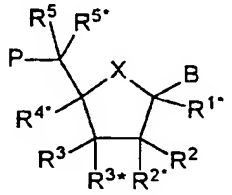
39. An oligomer according to any of the claims 1-38, wherein each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, R^{5*}, R^6, R^{6*}, R^7, and R^{7*} of the LNA(s), which are present and not involved in P, P* or the biradical(s), is independently selected from hydrogen, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, hydroxy, C_{1-6}-alkoxy, C_{2-6}-alkenyloxy, carboxy, C_{1-6}-alkoxycarbonyl, C_{1-6}-alkylcarbonyl, formyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, azido, C_{1-6}-alkanoyloxy, sulphono, sulphanyl, C_{1-6}-alkylthio, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and

each Nu independently designates a nucleoside selected from naturally occurring nucleosides and nucleoside analogues;

each LNA independently designates a nucleoside analogue;

each L independently designates an internucleoside linkage between two groups selected from Nu and LNA, or L together with G* designates a 3'-terminal group; and

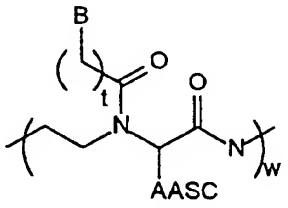
each LNA-L independently designates a nucleoside analogue of the general formula I:



I

wherein the substituents B, P, P*, R^{1*}, R^2, R^{2*}, R^3, R^{4*}, R^5, and R^{5*}, and X are as defined in claims 1-42.

44. An oligomer according to any of the claims 1-42, further comprising a PNA mono- or oligomer segment of the formula



wherein B is a defined above for the formula I, AASC designates hydrogen or an amino acid side chain, t is 1-5, and w is 1-50.

45. An oligomer according to any of the claims 1-44, which has an increased specificity towards complementary ssRNA or ssDNA compared to the native oligonucleotide.

46. An oligomer according to any of the claims 1-44, which has an increased affinity towards complementary ssRNA or ssDNA compared to the native oligonucleotide.

corresponding unmodified reference oligonucleotide which does not comprise any nucleoside analogues.

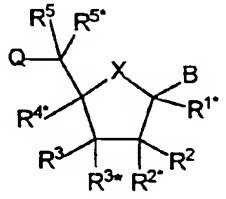
56. An oligomer according to claim 52, wherein said oligomer, when hybridised with a partially complementary RNA oligonucleotide having one or more mismatches with said oligomer, exhibits a reduction in T_m, as a result of said mismatches, which is equal to or greater than the reduction which would be observed with the corresponding unmodified reference oligonucleotide which does not comprise any nucleoside analogues.

57. An oligomer according to claim 50 or 52, which has substantially the same sensitivity of T_m to the ionic strength of the hybridisation buffer as that of the corresponding unmodified reference oligonucleotide.

58. An oligomer according to claim 50 or 52, which is at least 30% modified.

59. An oligomer according to claim 50 or 52, which has substantially higher 3'-exonucleolytic stability than the corresponding unmodified reference oligonucleotide.

60. A nucleoside analogue (hereinafter LNA) of the general formula II



II

wherein the substituent B is selected from nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands;

X is selected from -O-, -S-, -N(R^{N*})-, and -C(R^6R^{6*})-;

one of the substituents R^2, R^{2*}, R^3, and R^{3*} is a group Q*;

photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and/or two adjacent (non-geminal) R^* may together designate a double bond, and each of r and s is 0-3 with the proviso that the sum r+s is 1-4;

each of the substituents R^{1*}, R^2, R^{2*}, R^3, R^{4*}, R^5, and R^{6*}, which are not involved in Q, Q^* or the biradical, is independently selected from hydrogen, optionally substituted C_{1-12}-alkyl, optionally substituted C_{2-12}-alkenyl, optionally substituted C_{2-12}-alkynyl, hydroxy, C_{1-12}-alkoxy, C_{2-12}-alkenyloxy, carboxy, C_{1-12}-alkoxycarbonyl, C_{1-12}-alkylcarbonyl, formyl, aryl, aryloxy-carbonyl, aryloxy, arylcarbonyl, heteroaryl, heteroaryloxy-carbonyl, heteroaryloxy, heteroarylcarbonyl, amino, mono- and di(C_{1-6}-alkyl)amino, carbamoyl, mono- and di(C_{1-6}-alkyl)-amino-carbonyl, amino-C_{1-6}-alkyl-aminocarbonyl, mono- and di(C_{1-6}-alkyl)amino-C_{1-6}-alkyl-aminocarbonyl, C_{1-6}-alkyl-carbonylamino, carbamido, C_{1-6}-alkanoyloxy, sulphono, C_{1-6}-alkylsulphonyloxy, nitro, azido, sulphanyl, C_{1-6}-alkylthio, halogen, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, where aryl and heteroaryl may be optionally substituted, and where two geminal substituents together may designate oxo, thioxo, imino, or optionally substituted methylene, or together may form a spiro biradical consisting of a 1-5 carbon atom(s) alkylene chain which is optionally interrupted and/or terminated by one or more heteroatoms/groups selected from -O-, -S-, and -(NR^N)- where R^N is selected from hydrogen and C_{1-4}-alkyl, and where two adjacent (non-geminal) substituents may designate an additional bond resulting in a double bond; and R^{N*}, when present and not involved in a biradical, is selected from hydrogen and C_{1-4}-alkyl;

and basic salts and acid addition salts thereof;

with the first proviso that,

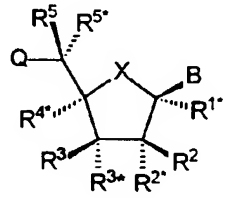
(i) R^2 and R^3 do not together designate a biradical selected from -O-CH_2-CH_2- and -O-CH_2-CH_2-CH_2-; and

(ii) R^3 and R^5 do not together designate a biradical selected from -CH_2-CH_2-, -O-CH_2-, and -O-Si(^{i}Pr)$_2$-O-Si(^{i}Pr)$_2$-O-;

optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyl, optionally substituted C_{2-6}-alkynyloxy, monophosphate, diphosphate, triphosphate, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, ligands, carboxy, sulphono, hydroxymethyl, Prot-O-CH_2-, aminomethyl, Prot-N(R^H)-CH_2-, carboxymethyl, sulphonomethyl, where Prot is a protection group for -OH, -SH, and -NH(R^H), respectively, and R^H is selected from hydrogen and C_{1-6}-alkyl; and

Q* is selected from hydrogen, azido, halogen, cyano, nitro, hydroxy, Act-O-, mercapto, Act-S-, C_{1-6}-alkylthio, amino, Act-N(R^H)-, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyl, optionally substituted C_{2-6}-alkynyloxy, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, ligands, carboxy, sulphono, where Act is an activation group for -OH, -SH, and -NH(R^H), respectively, and R^H is selected from hydrogen and C_{1-6}-alkyl.

67. A nucleotide analogue according to any of the claims 60-66, having the general formula IIa



IIa

wherein the substituents Q, B, R^{1*}, R^2, R^{2*}, R^3, R^{3*}, R^{4*}, R^5, and R^{5*} are as defined in claims 60-66.

68. A nucleoside analogue according to claim 67, wherein R^{3*} designates P*.

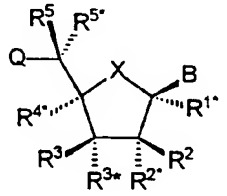
69. A nucleoside analogue according to claim 68, wherein R^{2*} and R^{4*} together designate a biradical.

substituted C_{1-6}-alkyl, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands, and any remaining substituents R* are hydrogen.

81. A nucleoside analogue according to any of the claims 68-80, wherein a group R* in the biradical of at least one LNA is selected from DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands.

82. A nucleoside analogue according to any of the claims 68-81, wherein the LNA(s) has/have the general formula Ia.

83. A nucleoside analogue according to claim 60 of the general formula IIa



IIa

wherein X is -O-;

B is selected from nucleobases, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, and ligands;

R^{3*} is a group Q*;

each of Q and Q* is independently selected from hydrogen, azido, halogen, cyano, nitro, hydroxy, Prot-O-, Act-O-, mercapto, Prot-S-, Act-S-, C_{1-6}-alkylthio, amino, Prot-$N(R^H)$-, Act-$N(R^H)$-, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyl, optionally substituted C_{2-6}-alkynyloxy, monophosphate, diphosphate, triphosphate, DNA intercalators, photochemically active groups, thermochemically active groups, chelating groups, reporter groups, ligands, carboxy, sulphono, hydroxymethyl, Prot-O-CH_2-, Act-O-CH_2-, aminomethyl, Prot-$N(R^H)$-CH_2-, Act-$N(R^H)$-CH_2-, carboxymethyl, sulphonomethyl, where

chelating groups, reporter groups, and ligands, and any remaining substituents R* are hydrogen.

85. A nucleotide analogue according to any of the claims 83-84, wherein the biradical is selected from -O-, $-(CH_2)_{0-1}-O-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-S-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-N(R^N)-(CH_2)_{1-3}-$, and $-(CH_2)_{2-4}-$.

86. A nucleoside analogue according to claim 85, wherein the biradical is selected from $-O-CH_2-$, $-S-CH_2-$ and $-N(R^N)-CH_2-$.

87. A nucleoside analogue according to any of the claims 83-86, wherein B is selected from nucleobases.

88. A nucleoside analogue according to claim 87, wherein the oligomer comprises at least one LNA wherein B is selected from adenine and guanine and at least one LNA wherein B is selected from thymine, cytosine and urasil.

89. A nucleoside analogue according to claim 83, wherein B designates a nucleobase, X is -O-, R^{2*} and R^{4*} together designate a biradical selected from $-(CH_2)_{0-1}-O-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-S-(CH_2)_{1-3}-$, and $-(CH_2)_{0-1}-N(R^N)-(CH_2)_{1-3}-$ where R^N is selected from hydrogen and C_{1-4}-alkyl, Q designates Prot-O-, R^{3*} is Q* which designates Act-OH, and R^{1*}, R^2, R^3, R^5, and R^{5*} each designate hydrogen, wherein Act and Prot are as defined in claim 58.

90. A nucleoside analogue according to claim 83, wherein B designates a nucleobase, X is -O-, R^{2*} and R^{4*} together designate a biradical selected from $-(CH_2)_{0-1}-O-(CH_2)_{1-3}-$, $-(CH_2)_{0-1}-S-(CH_2)_{1-3}-$, and $-(CH_2)_{0-1}-N(R^N)-(CH_2)_{1-3}-$ where R^N is selected from hydrogen and C_{1-4}-alkyl, Q is selected from hydroxy, mercapto, C_{1-6}-alkylthio, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyloxy, monophosphate, diphosphate, and triphosphate, R^{3*} is Q* which is selected from hydrogen, azido, halogen, cyano, nitro, hydroxy, mercapto, C_{1-6}-alkylthio, amino, mono- or di(C_{1-6}-alkyl)amino, optionally substituted C_{1-6}-alkoxy, optionally substituted C_{1-6}-alkyl, optionally substituted C_{2-6}-alkenyl, optionally substituted C_{2-6}-alkenyloxy, optionally substituted C_{2-6}-alkynyl, and

95. The use according to claim 93, wherein the incorporation of LNA modulates the ability of the oligonucleotide to act as a substrate for nucleic acid active enzymes.

96. The use of an LNA as defined in any of the claims 60-92 for the preparation of a conjugate of an LNA modified oligonucleotide and a compound selected from proteins, amplicons, enzymes, polysaccharides, antibodies, haptens, peptides, and PNA.

97. A conjugate of an LNA modified oligonucleotide (an oligomer) as defined in any of the claims 1-59 and a compound selected from proteins, amplicons, enzymes, polysaccharides, antibodies, haptens, peptides, and PNA.

98. The use of an LNA as defined in any of the claims 60-92 as a substrate for enzymes active on nucleic acids.

99. The use according to claim 98, wherein the substituent Q in the formula I in claim 60 designates a triphosphate,

100. The use according to claim 98, wherein the LNA is used as a substrate for DNA and RNA polymerases.

101. The use of an LNA as defined in any of the claims 60-92 as a therapeutic agent.

102. The use of an LNA as defined in any of the claims 60-92 for diagnostic purposes.

103. A solid support material having immobilised thereto an optionally nucleobase protected and optionally 5'-OH protected LNA.

104. The use of one or more LNA as defined in any of the claims 60-92 in the construction of solid surface onto which LNA modified oligonucleotides of different sequences are attached .

115. The use of an LNA modified oligonucleotide (an oligomer) as defined in any of the claims 1-59 in diagnostics, e.g. for the isolation, purification, amplification, detection, identification, quantification, or capture of natural or synthetic nucleic acids.

116. The use according to claim 115, wherein the oligonucleotide comprises a photochemically active group, a thermochemically active group, a chelating group, a reporter group, or a ligand that facilitates the direct of indirect detection of the oligonucleotide or the immobilisation of the oligonucleotide onto a solid support.

117. The use according to claim 116, wherein the photochemically active group, the thermochemically active group, the chelating group, the reporter group, or the ligand includes a spacer (K), said spacer comprising a chemically cleavable group.

118. The use according to claim 116, wherein the photochemically active group, the thermochemically active group, the chelating group, the reporter group, or the ligand is attached via the biradical (i.e. as R^*) of at least one of the LNA(s) of the oligonucleotide.

119. The use according to claim 115 for capture and detection of naturally occurring or synthetic double stranded or single stranded nucleic acids such as RNA or DNA.

120. The use according to claim 115 for purification of naturally occurring double stranded or single stranded nucleic acids such as RNA or DNA.

121. The use according to claim 115 as a probe in in-situ hybridisation, in Southern hydridisation, Dot blot hybridisation, reverse Dot blot hybridisation, or in Northern hybridisation.

122. The use according to claim 115 in the construction of an affinity pair.

123. The use according to claim 115 as a primer in a nucleic acid sequencing reaction or primer extension reactions.

134. The use of an LNA modified oligonucleotide (an oligomer) as defined in any of the claims 1-59 to hybridise to non-protein coding cellular RNAs, such as tRNA, rRNA, snRNA and scRNA, *in vivo* or *in-vitro*.

135. The use of an LNA modified oligonucleotide (an oligomer) as defined in any of the claims 1-59 in the construction of an oligonucleotide containing a fluorophor and a quencher, positioned in such a way that the hybridised state of the oligonucleotide can be distinguished from the unbound state of the oligonucleotide by an increase in the fluorescent signal from the probe.

136. The use of an LNA modified oligonucleotide (an oligomer) as defined in any of the claims 1-59 in the construction of Taqman probes or Molecular Beacons.

137. A kit for the isolation, purification, amplification, detection, identification, quantification, or capture of natural or synthetic nucleic acids, the kit comprising a reaction body and one or more LNA modified oligonucleotides (oligomer) as defined in any of the claims 1-59.

138. A kit according to claim 137, wherein the LNA modified oligonucleotides are immobilised onto said reactions body.

139. A kit for the isolation, purification, amplification, detection, identification, quantification, or capture of natural or synthetic nucleic acids, the kit comprising a reaction body and one or more LNAs as defined in any of the claims 60-92.

140. A kit according to claim 139, wherein the LNAs are immobilised onto said reactions body.

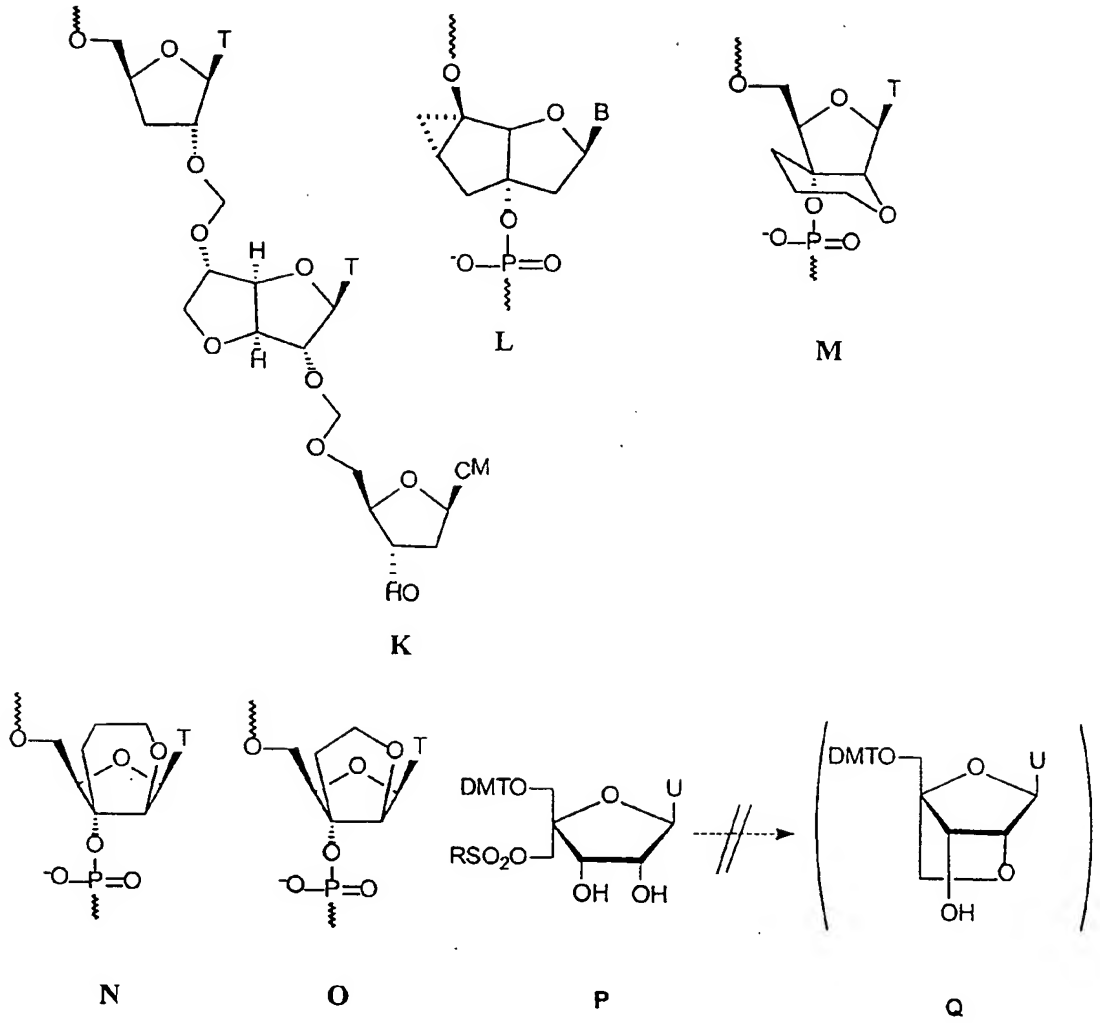


Fig. 1B

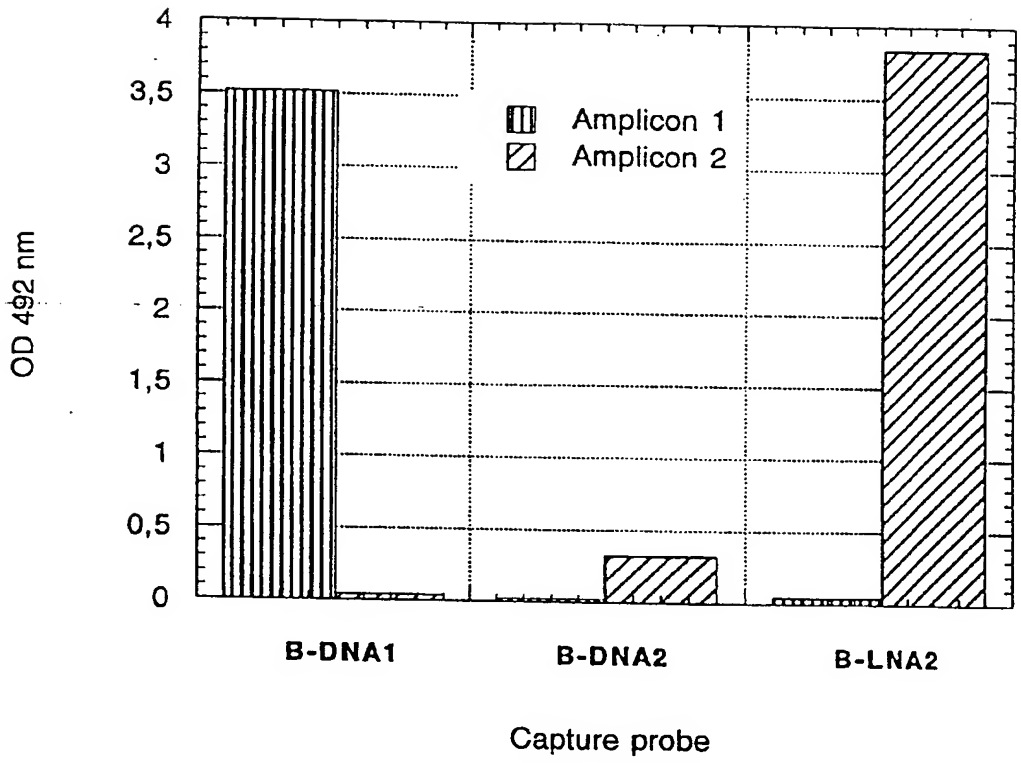

OD 492 nm
4
3,5
3
2,5
2
1,5
1
0,5
0
Amplicon 1
Amplicon 2
B-DNA1
B-DNA2
B-LNA2
Capture probe

Fig. 3

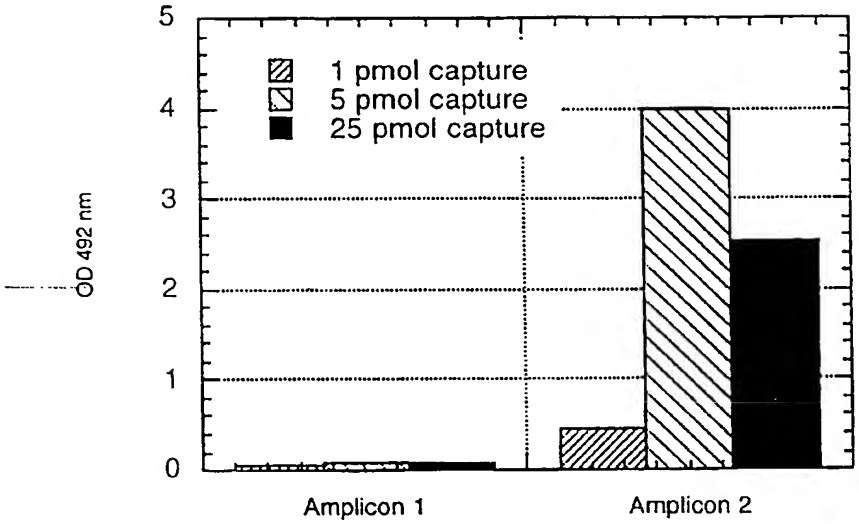

5
4
3
2
1
0
OD 492 nm
1 pmol capture
5 pmol capture
25 pmol capture
Amplicon 1
Amplicon 2

Fig. 4 B

1 2 3 4 5 6

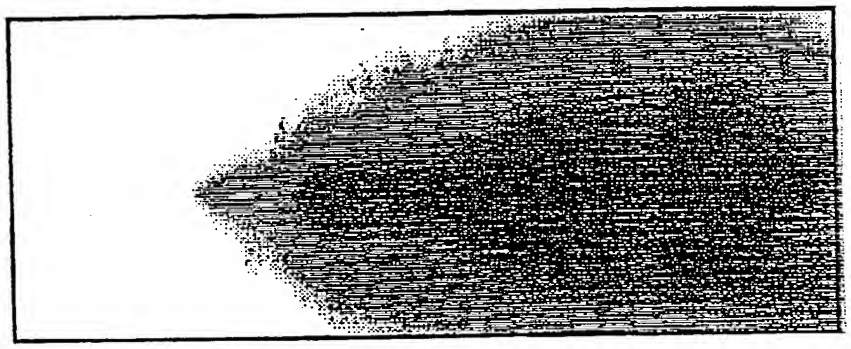


Fig. 6

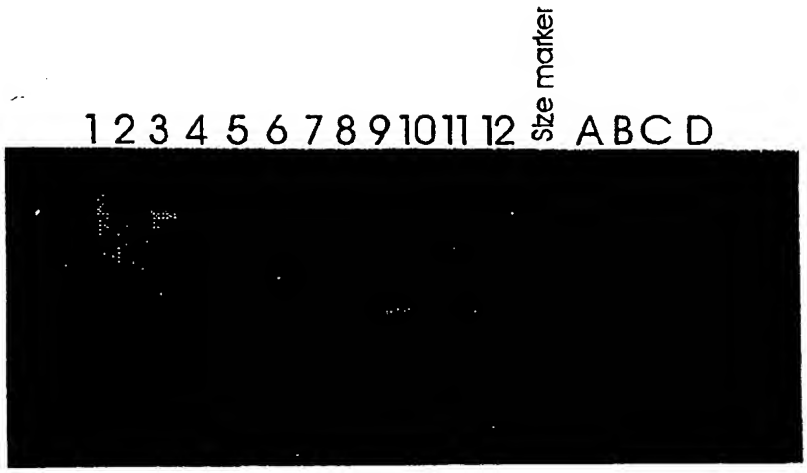


Fig. 8

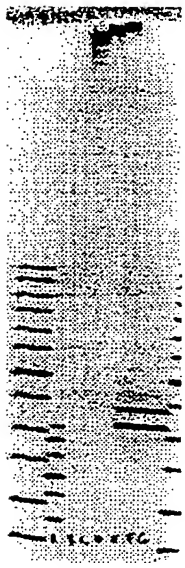


Fig. 10

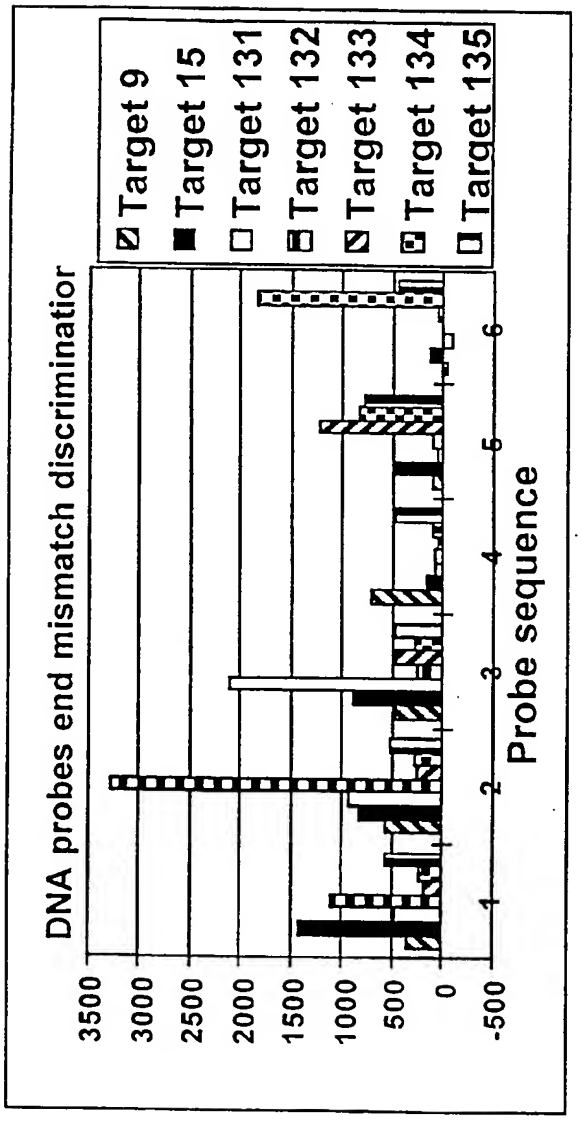

DNA probes end mismatch discriminatior
Target 9
Target 15
Target 131
Target 132
Target 133
Target 134
Target 135
3500
3000
2500
2000
1500
1000
500
0
-500
1
2
3
4
5
6
Probe sequence

Fig. 12

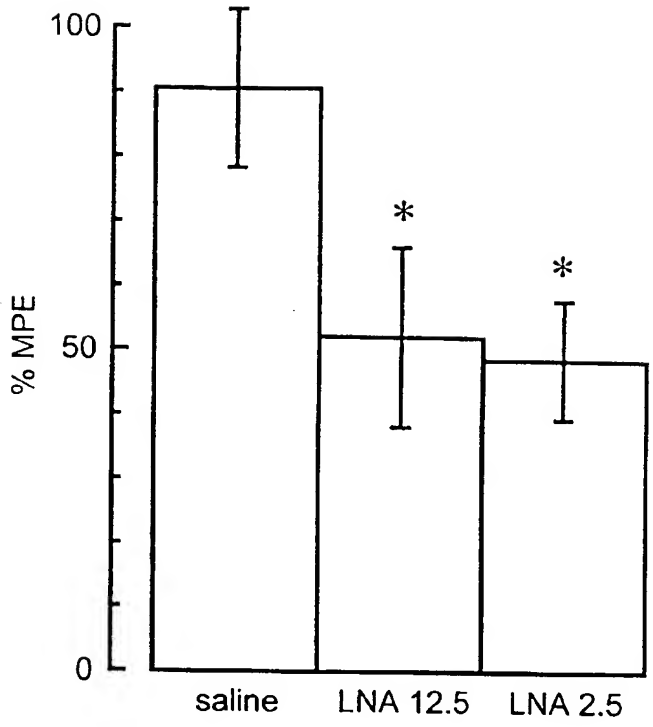


Fig. 14

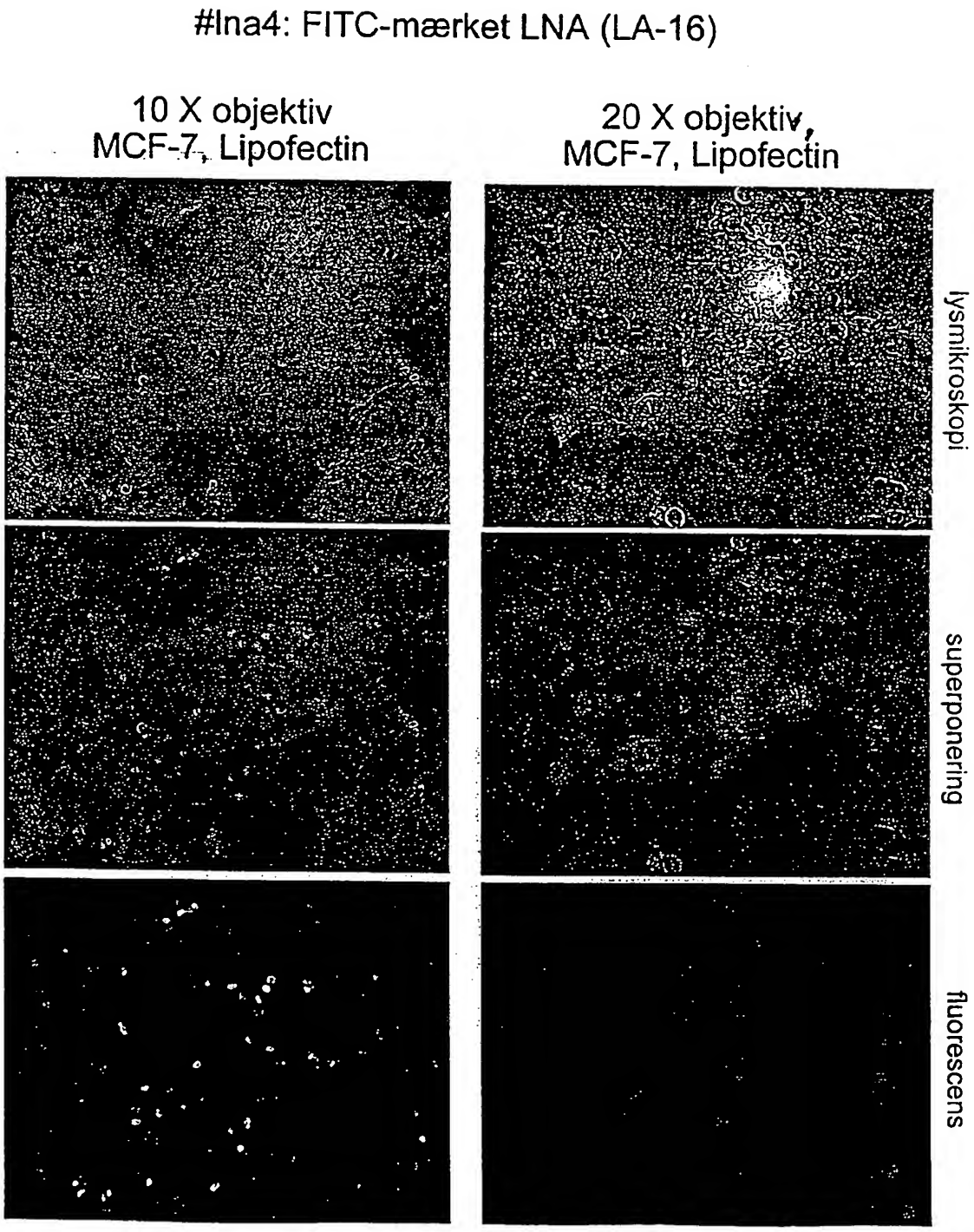

#lna4: FITC-mærket LNA (LA-16)
10 X objektiv
MCF-7, Lipofectin
20 X objektiv,
MCF-7, Lipofectin
lysmikroskopi
superponering
fluorescens

Fig. 16

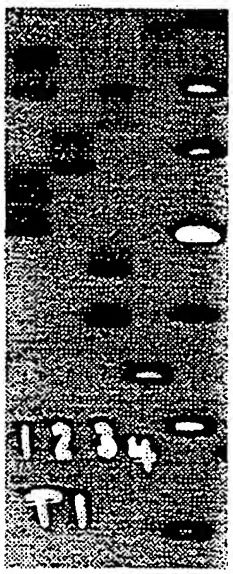


Fig. 18

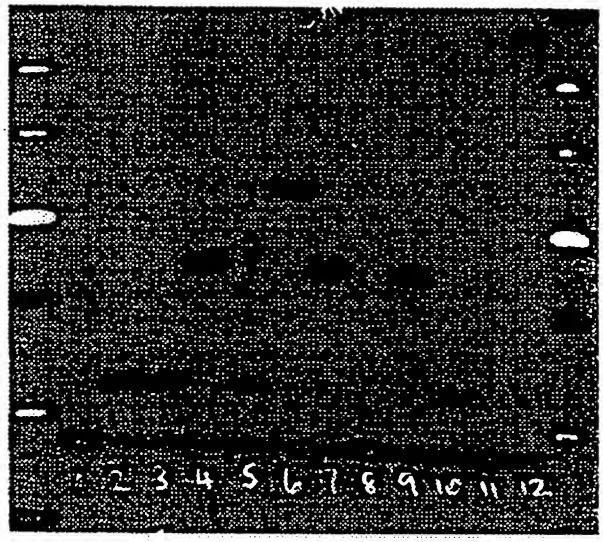


Fig. 20

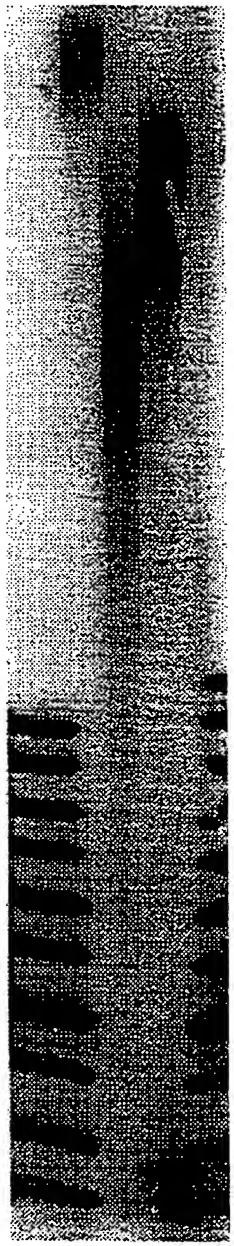


Fig. 22

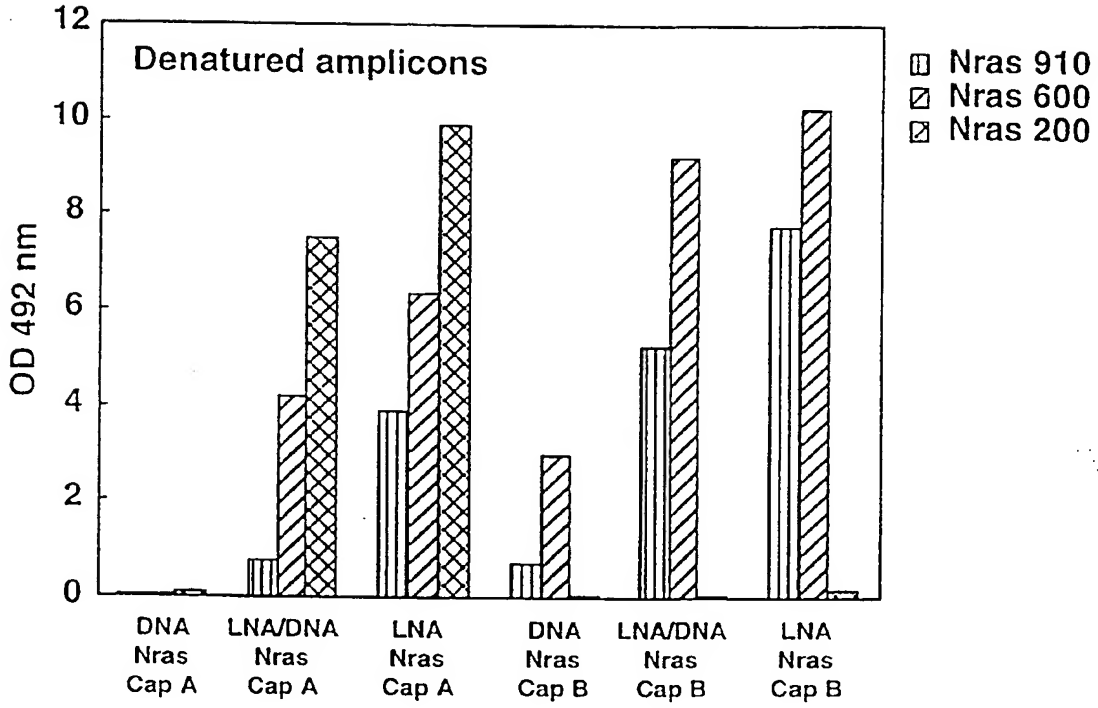

Denatured amplicons
OD 492 nm
0
2
4
6
8
10
12
Nras 910
Nras 600
Nras 200
DNA Nras Cap A
LNA/DNA Nras Cap A
LNA Nras Cap A
DNA Nras Cap B
LNA/DNA Nras Cap B
LNA Nras Cap B

Fig. 23 B

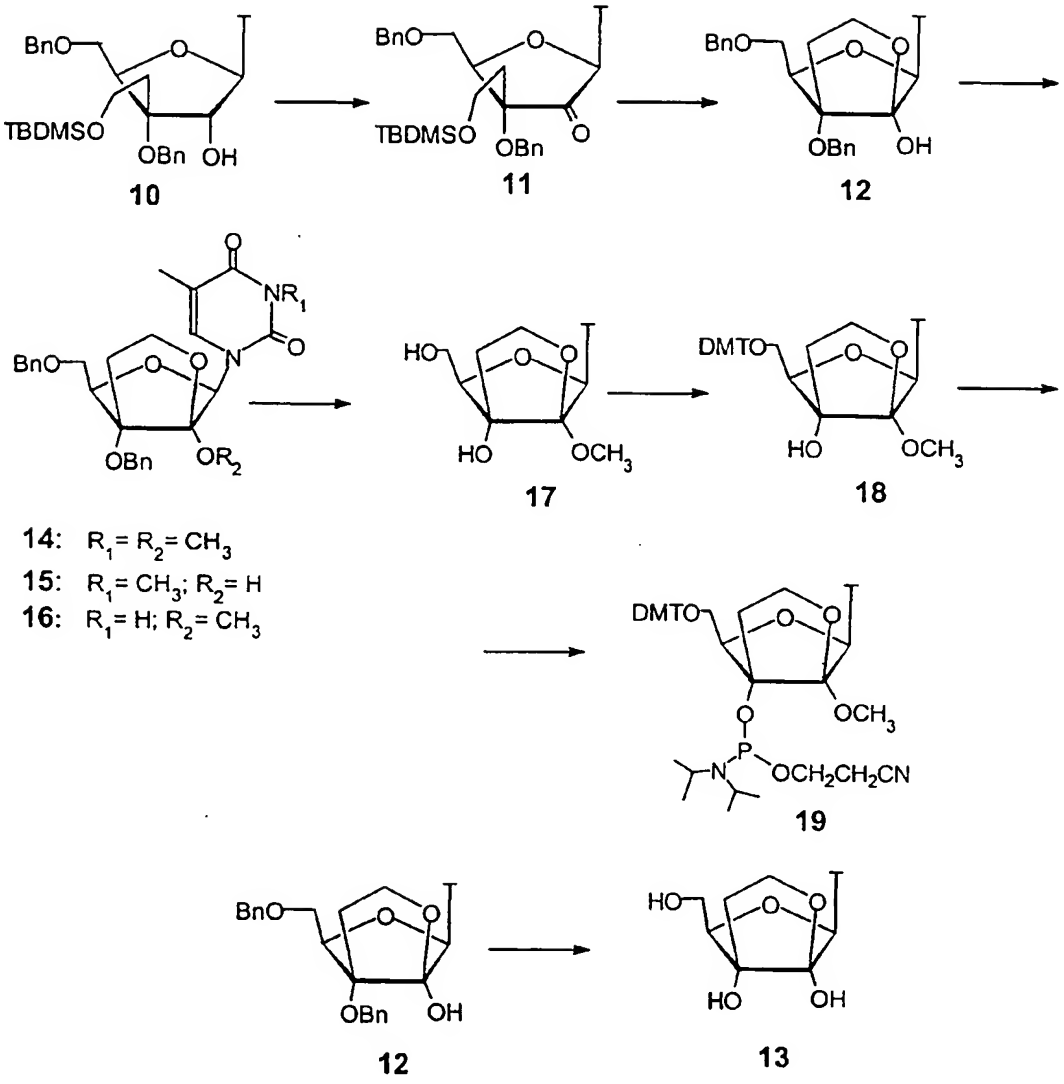

BnO
TBDMSO
OBn
OH
10
11
12
NR1
OR2
HO
OCH3
17
DMTO
18
14: R1= R2= CH3
15: R1= CH3; R2= H
16: R1= H; R2= CH3
OCH2CH2CN
19
13

Fig. 25

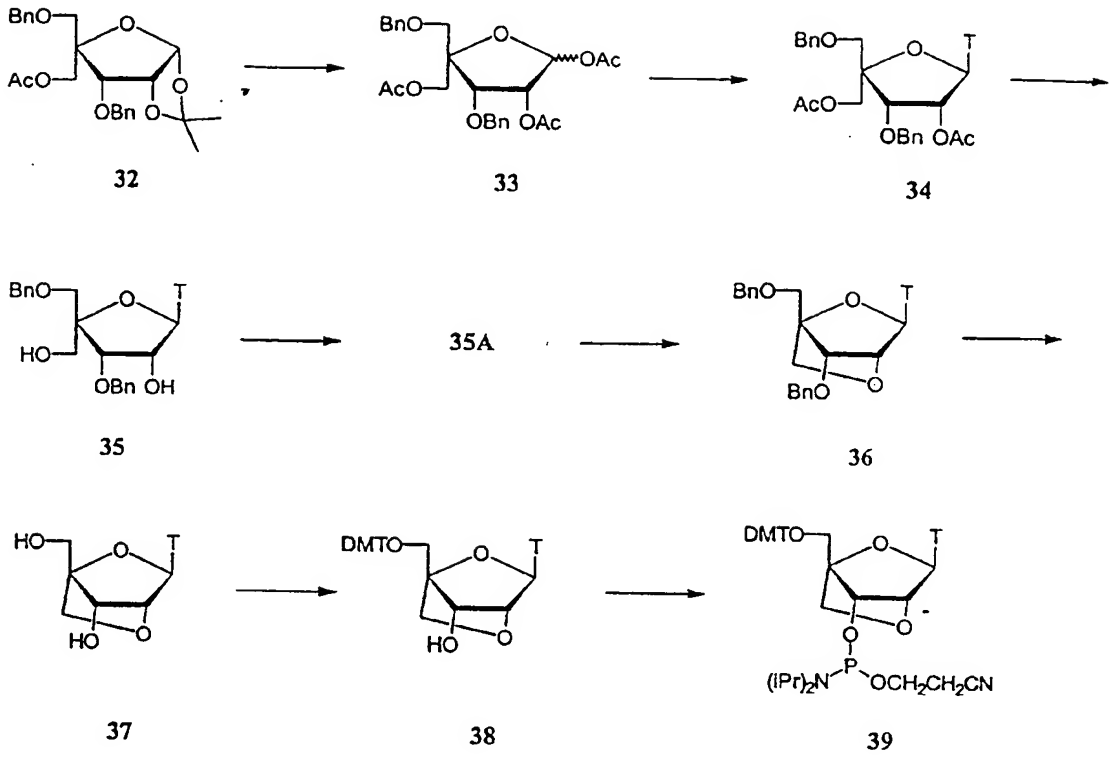

BnO
AcO
OBn
O
T
OAc
HO
OH
DMTO
(iPr)2N
P
OCH2CH2CN
32
33
34
35
35A
36
37
38
39

Fig. 27

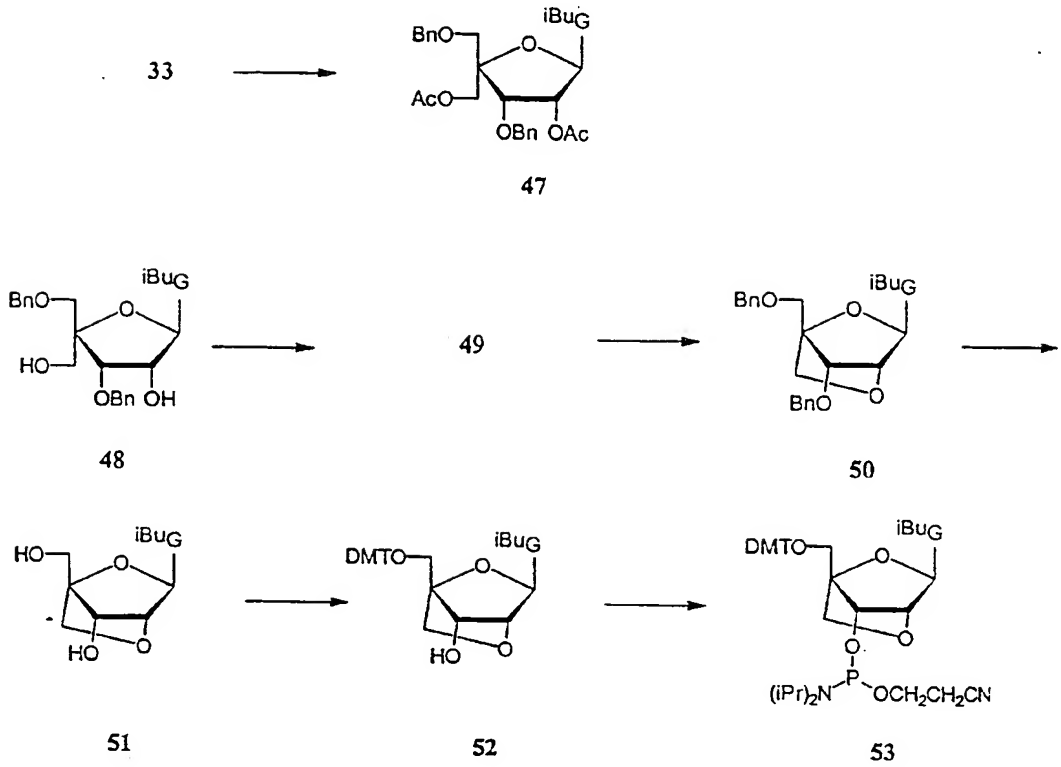


Fig. 29

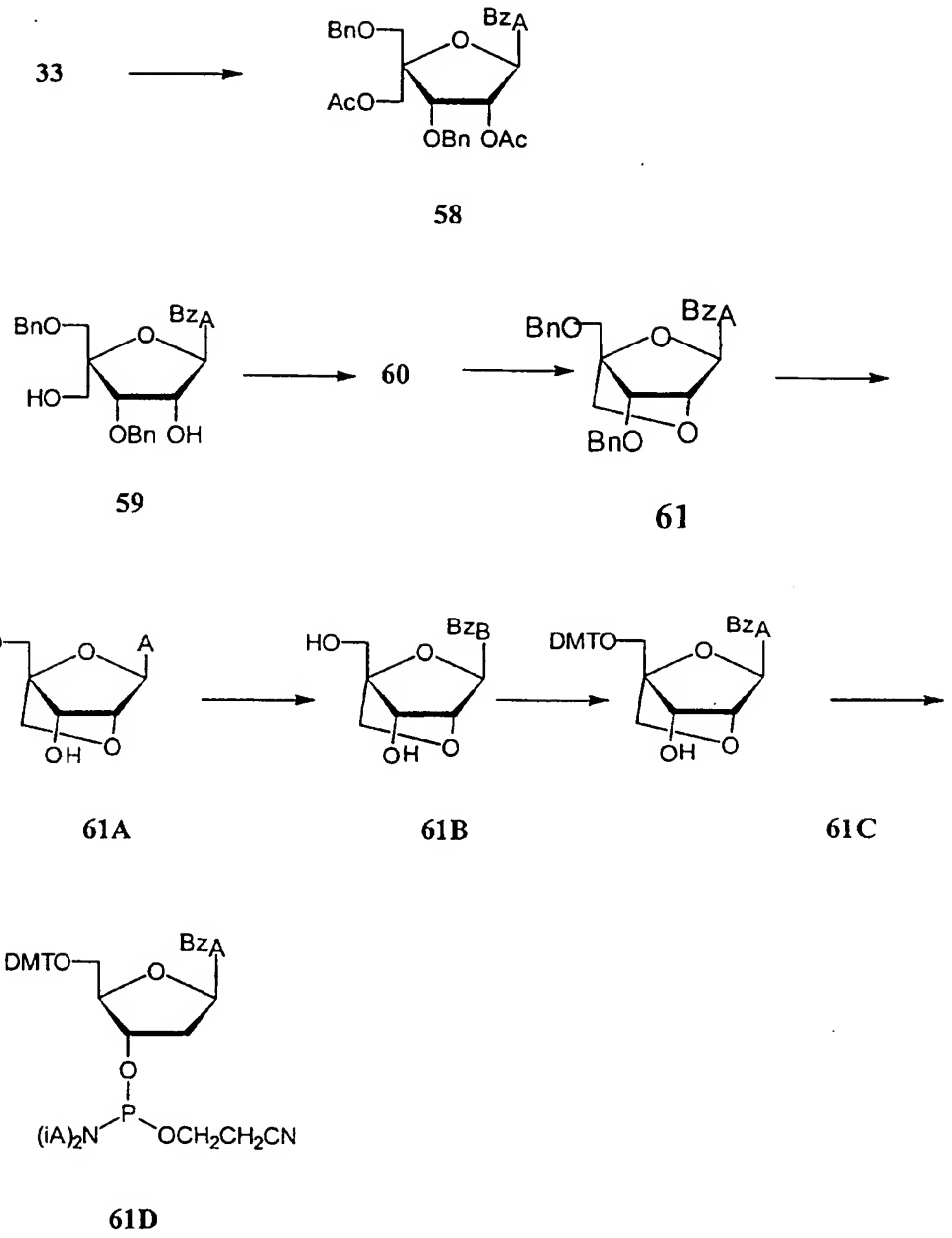
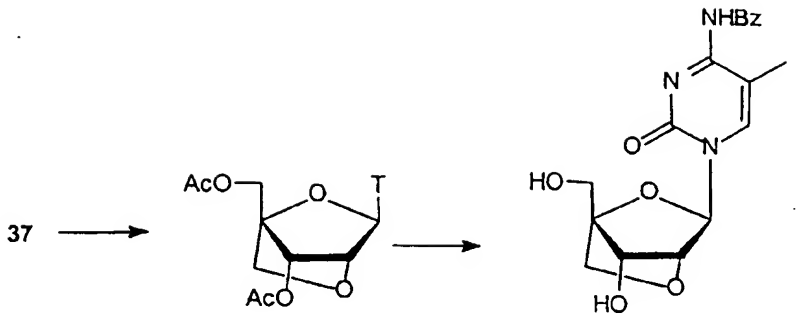
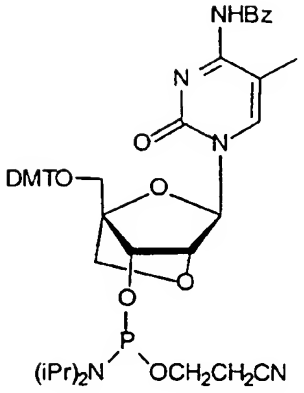

33
BnO
BzA
AcO
OBn OAc
58
BnO
BzA
HO
OBn OH
59
60
BnO
BzA
BnO
61
HO
A
OH
61A
HO
BzB
OH
61B
DMTO
BzA
OH
61C
DMTO
BzA
O
P
(iA)2N
OCH2CH2CN
61D

Fig. 31



64 65



66

Fig. 33

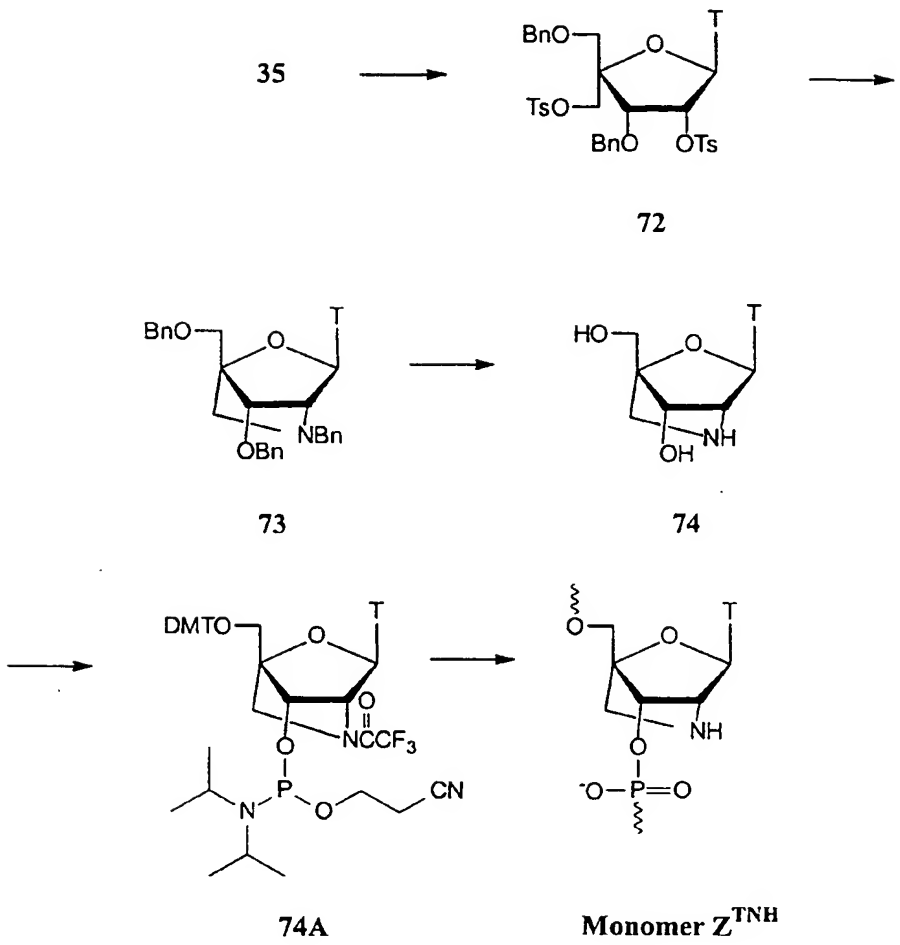

35
BnO
TsO
BnO
OTs
T
72
BnO
OBn
NBn
73
HO
OH
NH
74
DMTO
NCCF3
CN
74A
Monomer Z^TNH

Fig. 35

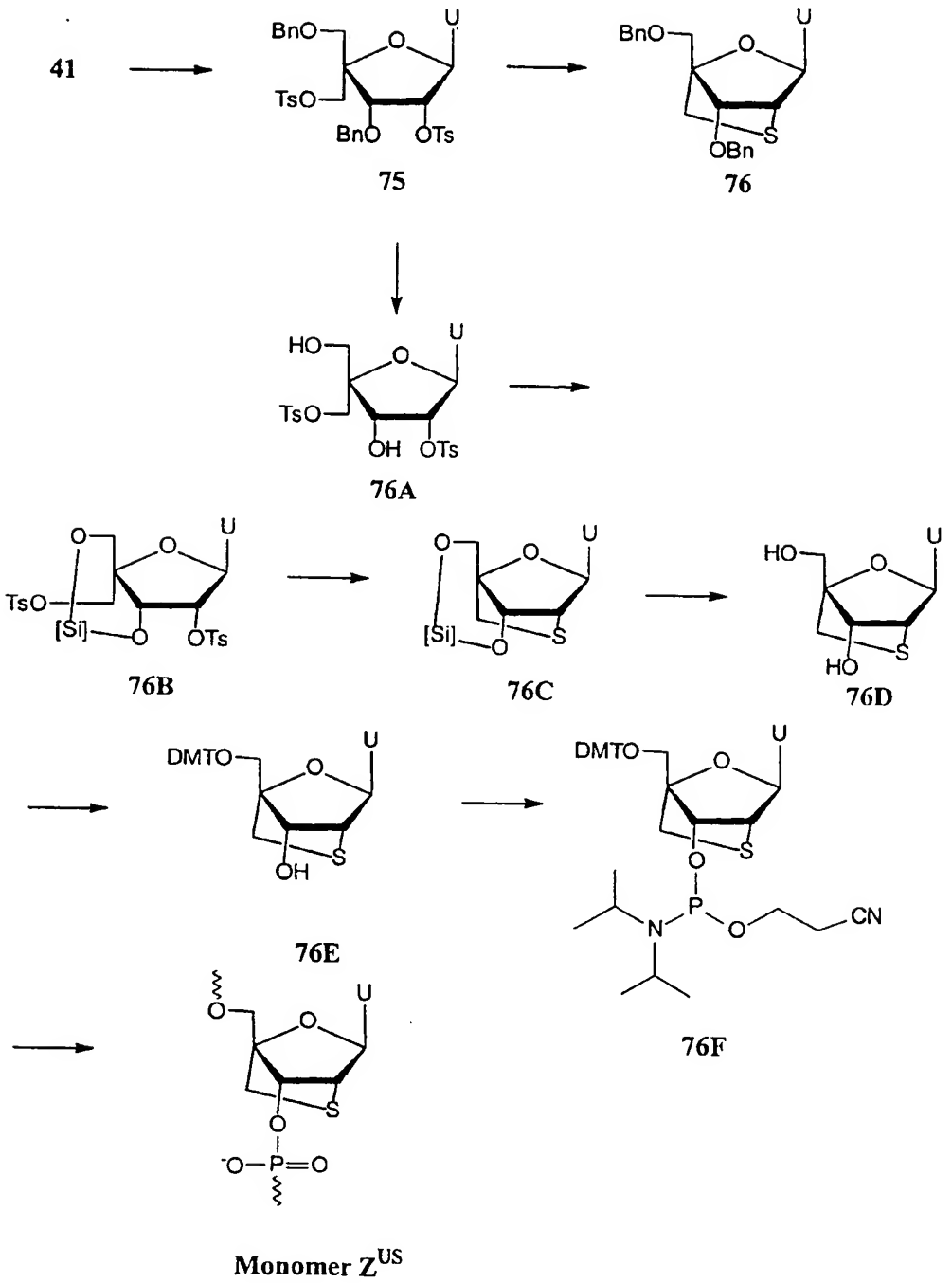

41
BnO
TsO
BnO
OTs
U
O
75
BnO
OBn
S
76
HO
TsO
OH
OTs
76A
TsO
[Si]
O
OTs
76B
[Si]
76C
HO
HO
76D
DMTO
OH
76E
DMTO
N
P
CN
76F
O—P=O
Monomer Z^US

Fig. 37

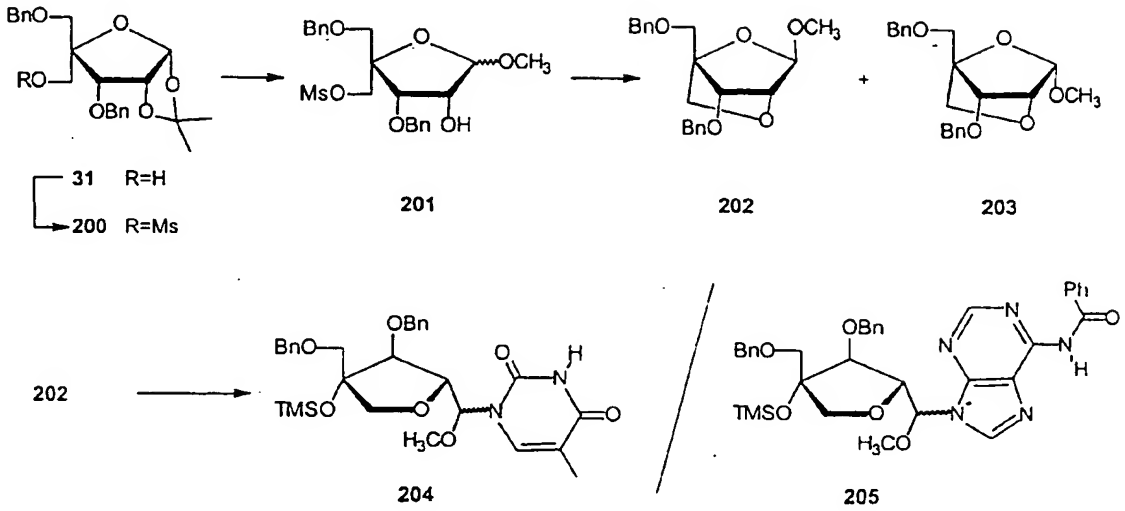

BnO
RO
OBn
O
31 R=H
200 R=Ms
MsO
OCH3
OBn OH
201
202
203
TMSO
H3CO
OBn
N
H
Ph
204
205

Fig. 39

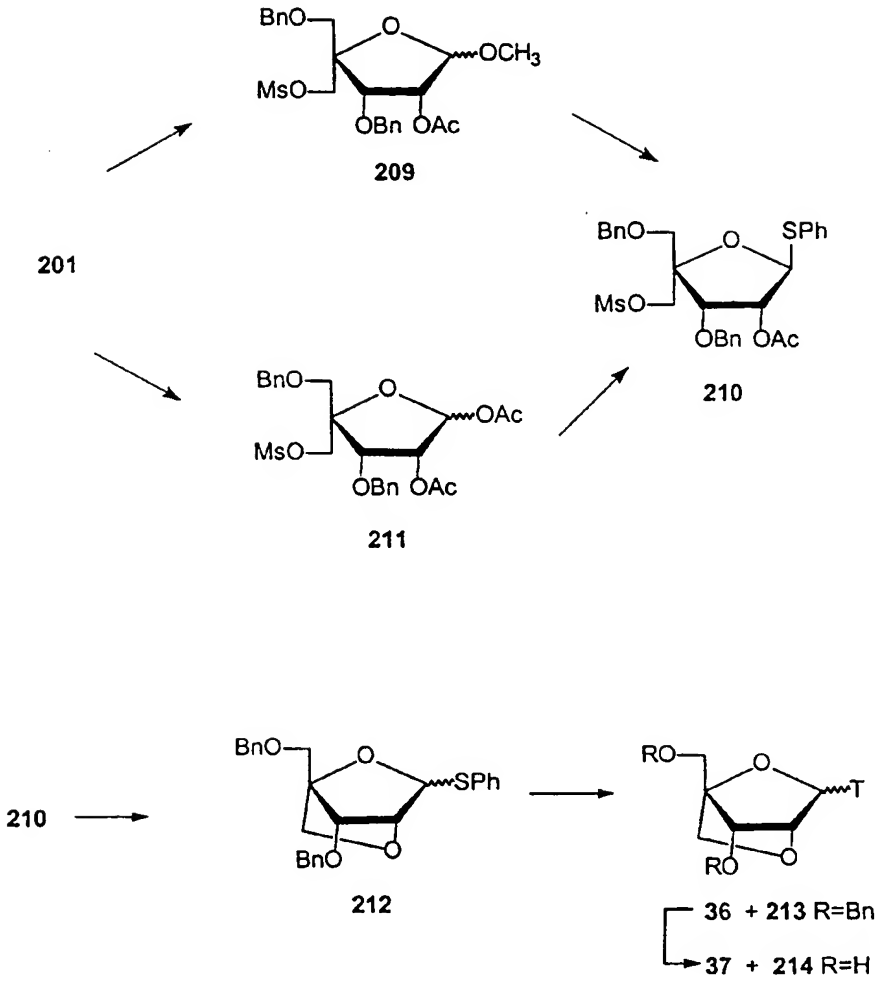

BnO
MsO
OBn OAc
OCH3
209
201
BnO
MsO
OBn OAc
SPh
210
BnO
MsO
OBn OAc
OAc
211
210
BnO
BnO
SPh
212
RO
RO
T
36 + 213 R=Bn
37 + 214 R=H

Fig. 41